PB86-107083

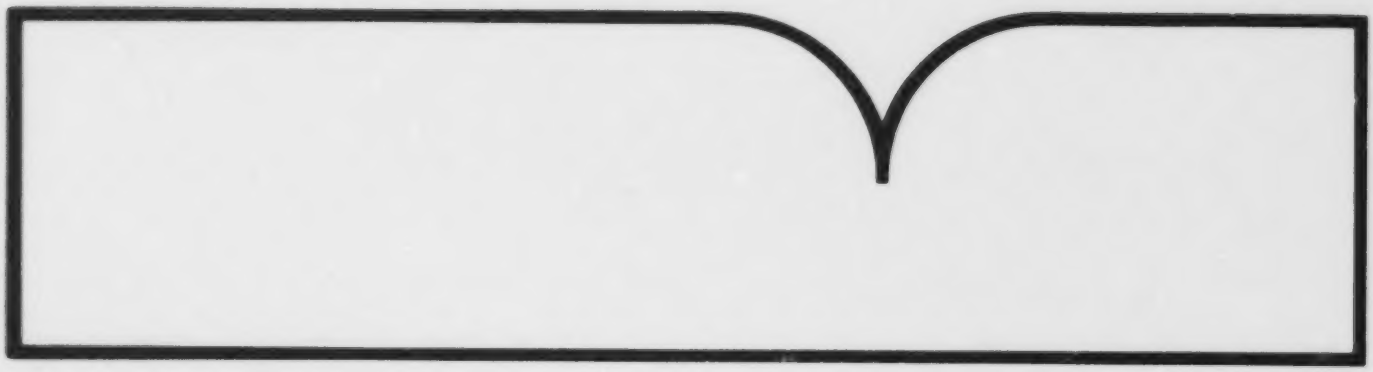
Methods for Assessing Exposure to Chemical Substances
Volume 1. Introduction

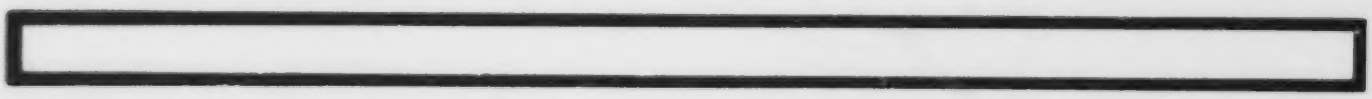
Versar, Inc., Springfield, VA

Prepared for

Environmental Protection Agency
Washington, DC

Jul 85





U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Office of
Toxic Substances
Washington, D.C. 20460

EPA 560/5-85-001
July 1985

PB86-107083

Toxic Substances

EPA

Methods for Assessing Exposure to Chemical Substances

Volume 1

Introduction

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. EPA 560/5-85-001	2.	3. Recipient's Accession No. PB86 107083/AS
4. Title and Subtitle: Methods for Assessing Exposure to Chemical Substances - Volume 1: Introduction			5. Report Date: 7/85 6.
7. Author(s): Michael A. Callahan, Gina H. Dixon, Stephen H. Nacht, Douglas A. Dixon, John J. Doria			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: Versar, Inc. 6850 Versar Center Springfield, Virginia 22151			10. Project/Task/Work Unit No. Task 9 11. Contract(C) or Grant(G) No. (C) EPA 68-02-3968 (G)
12. Sponsoring Organization Name and Address: U.S. Environmental Protection Agency Office of Toxic Substances Exposure Evaluation Division Washington, D.C. 20460			13. Type of Report & Period Covered: Final Report 14.

15. Supplementary Notes

EPA Project Officer for this report was Michael A. Callahan

16. Abstract (Limit: 200 words)

This document is the first in a series of volumes developed for the U.S. Environmental Protection Agency, Office of Toxic Substances to assist in the assessment of exposure to chemical substances. This introductory volume discusses issues of general interest in all exposure assessments, including a discussion on planning an assessment, and summarizes the contents of the next eight volumes.

Planning an exposure assessment is a function of the purpose, scope, depth, and approach of the assessment. The report presents a list of questions that, when answered, aid the assessor in determining the resources and tools needed to do the assessment. The organization of an exposure assessment is discussed, and a basic outline that can be used is provided. The content of major sections in an exposure assessment are discussed: General Information, Sources, Exposure Pathways and Environmental Fate, Monitoring or Estimated Concentrations, Exposed Populations, and the Integrated Exposure Analysis. An overview of exposure assessments in different settings is presented. Different types of assessments (screening level, intermediate level, detailed, and special assessments) are described.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

Exposure Assessment
Toxic Substances
Exposure Assessment Methods

c. COSATI Field/Group 44C

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Distribution Unlimited	Unclassified	103
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18) See Instructions on Reverse

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

EPA 560/5-85-001
July 1985

METHODS FOR ASSESSING EXPOSURE TO CHEMICAL SUBSTANCES

Volume 1

Introduction

by

Michael A. Callahan, Gina L. Dixon, Stephen H. Nacht,
Douglas A. Dixon, John J. Doria

EPA Contract No. 68-02-3968

Project Officer
Michael A. Callahan

Exposure Evaluation Division
Office of Toxic Substances
Washington, D.C. 20460

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF PESTICIDES AND TOXIC SUBSTANCES
WASHINGTON, D.C. 20460

DISCLAIMER

This document has been reviewed and approved for publication by the Office of Toxic Substances, Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency. The use of trade names or commercial products does not constitute Agency endorsement or recommendation for use.

FOREWORD

This document is one of a series of volumes, developed for the U.S. Environmental Protection Agency (EPA), Office of Toxic Substances (OTS), that provides methods and information useful for assessing exposure to chemical substances. The methods described in these volumes have been identified by EPA-OTS as having utility in exposure assessments on existing and new chemicals in the OTS program. These methods are not necessarily the only methods used by OTS, because the state-of-the-art in exposure assessment is changing rapidly, as is the availability of methods and tools. There is no single correct approach to performing an exposure assessment, and the methods in these volumes are accordingly discussed only as options to be considered, rather than as rigid procedures.

Perhaps more important than the optional methods presented in these volumes is the general information catalogued. These documents contain a great deal of non-chemical-specific data which can be used for many types of exposure assessments. This information is presented along with the methods in individual volumes and appendices. As a set, these volumes should be thought of as a catalog of information useful in exposure assessment, and not as a "how-to" cookbook on the subject.

The definition, background, and discussion of planning exposure assessments are discussed in the introductory volume of the series (Volume 1). Each subsequent volume addresses only one general exposure setting. Consult Volume 1 for guidance on the proper use and interrelations of the various volumes and on the planning and integration of an entire assessment.

The titles of the nine basic volumes are as follows:

Volume 1	Methods for Assessing Exposure to Chemical Substances (EPA 560/5-85-001)
Volume 2	Methods for Assessing Exposure to Chemical Substances in the Ambient Environment (EPA 560/5-85-002)
Volume 3	Methods for Assessing Exposure from Disposal of Chemical Substances (EPA 560/5-85-003)
Volume 4	Methods for Enumerating and Characterizing Populations Exposed to Chemical Substances (EPA 560/5-85-004)
Volume 5	Methods for Assessing Exposure to Chemical Substances in Drinking Water (EPA 560/5-85-005)

Preceding page blank

Volume 6 Methods for Assessing Occupational Exposure to Chemical Substances (EPA 560/5-85-006)

Volume 7 Methods for Assessing Consumer Exposure to Chemical Substances (EPA 560/5-85-007)

Volume 8 Methods for Assessing Environmental Pathways of Food Contamination (EPA 560/5-85-008)

Volume 9 Methods for Assessing Exposure to Chemical Substances Resulting from Transportation-Related Spills (EPA 560/5-85-009)

Because exposure assessment is a rapidly developing field, its methods and analytical tools are quite dynamic. EPA-OTS intends to issue periodic supplements for Volumes 2 through 9 to describe significant improvements and updates for the existing information, as well as adding short monographs to the series on specific areas of interest. The first four of these monographs are as follows:

Volume 10 Methods for Estimating Uncertainties in Exposure Assessments (EPA 560/5-85-014)

Volume 11 Methods for Estimating the Migration of Chemical Substances from Solid Matrices (EPA 560/5-85-015)

Volume 12 Methods for Estimating the Concentration of Chemical Substances in Indoor Air (EPA 560/5-85-016)

Volume 13 Methods for Estimating Retention of Liquids on Hands (EPA 560/5-85-017)

Michael A. Callahan, Chief
Exposure Assessment Branch
Exposure Evaluation Division (TS-798)
Office of Toxic Substances

ACKNOWLEDGEMENTS

This report was prepared by Versar Inc. of Springfield, Virginia, for the EPA Office of Toxic Substances, Exposure Evaluation Division, Exposure Assessment Branch (EAB) under EPA Contract No. 68-01-6271 (Task 42) and Contract No. 68-02-3968 (Task 9). The EPA-EAB Program Manager was Michael A. Callahan; his support and guidance is gratefully acknowledged.

A number of Versar personnel have contributed to this task over the three-year period of performance as shown below:

Program Management	-	Gayaneh Contos
Task Management	-	Gina Dixon
Technical Support	-	John Doria Douglas Dixon
Editing	-	Juliet Crumrine
Secretarial/Clerical	-	Shirley Harrison Lucy Gentry Donna Barnard

TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	1
1.1	Background	2
1.2	Purpose and Scope	2
2.	PLANNING AN EXPOSURE ASSESSMENT	5
2.1	Purpose of Exposure Assessments	6
2.2	Scope	7
2.3	Depth	9
2.4	Approach	11
2.5	Summary	14
3.	ORGANIZATION AND CONTENTS OF AN EXPOSURE ASSESSMENT	15
3.1	General Information	17
3.2	Sources	17
3.3	Exposure Pathways and Environmental Fate	18
3.4	Monitoring or Estimated Concentrations	19
3.5	Exposed Populations	20
3.6	Integrated Exposure Analysis	20
4.	OVERVIEW AND INTEGRATION OF SETTINGS	23
4.1	Exposure to Chemical Substances in the Ambient Environment	23
4.2	Exposure from Disposal of Chemical Substances	27
4.3	Populations Exposed to Chemical Substances	29
4.4	Exposure to Chemical Substances in Drinking Water	32
4.5	Occupational Exposure	34
4.6	Consumer Exposure	36
4.7	Environmental Pathways of Food Contamination	38
4.8	Exposure from Transportation-Related Spills	39
5.	TYPES OF EXPOSURE ASSESSMENTS	41
5.1	Screening Level Assessments	41
5.2	Intermediate Level Exposure Assessments	43
5.3	Detailed Exposure Assessments	44
5.4	Special Exposure Assessments	45

Preceding page blank

TABLE OF CONTENTS (continued)

	Page No.
6. GLOSSARY	47
7. ABBREVIATIONS	59
8. REFERENCES	63
APPENDIX	65

LIST OF TABLES

Page No.

Table 1. Suggested Outline for an Exposure Assessment 16

Table 2. Exposure Assessment Needs for Various Exposure Settings 24

1. INTRODUCTION

This volume is the first of a series of 9 volumes addressing methods for assessing exposures to chemical substances. The reports are being developed for the U.S. Environmental Protection Agency (EPA), Office of Toxic Substances (OTS). This volume presents information on planning and performing exposure assessments for chemical substances and provides an overview of the other eight volumes in the series. The following companion volumes provide methods and supporting information for assessing exposures in each of the following exposure categories or settings:

- Volume 2 - Methods for Assessing Exposure to Chemical Substances in the Ambient Environment
- Volume 3 - Methods for Assessing Exposure From Disposal of Chemical Substances
- Volume 4 - Methods for the Enumerating and Characterizing Populations Exposed to Chemical Substances
- Volume 5 - Methods for Assessing Exposure to Chemical Substances in Drinking Water
- Volume 6 - Methods for Assessing Occupational Exposure to Chemical Substances
- Volume 7 - Methods for Assessing Consumer Exposure to Chemical Substances
- Volume 8 - Methods for Assessing Environmental Pathways of Food Contamination
- Volume 9 - Methods for Estimating Exposure to Chemical Substances Resulting from Transportation-Related Spills

The purpose and scope of this volume and the entire methods series are discussed in this section. Section 2 of this volume discusses the planning of an exposure assessment; Section 3 discusses the components of an exposure assessment; Section 4 provides an overview of the methods

for assessing exposure in each exposure category; and Section 5 discusses the different types of exposure assessments that may be performed (depending on the level of detail required and the information available). A glossary of the terms used in exposure assessments is presented in Section 6. An appendix presents the Table of Contents from each of the other methods volumes.

1.1 Background

Under the Toxic Substances Control Act (TSCA) of 1976 (P.L. 94-469), the U.S. Environmental Protection Agency (EPA) must evaluate the risks to human health and the environment from the manufacture, processing, distribution in commerce, use, and disposal of new and existing chemical substances. An evaluation of risk includes, by definition, exposure assessment; OTS is responsible for performing all TSCA exposure assessments.

1.2 Purpose and Scope

Performing an exposure assessment may be fairly simple, or it may be an extremely complicated task. Exposure assessments can be very different from one another in scope, depth, or approach. This can complicate any attempt to develop exposure assessment methods or procedures that apply to all (or at least most) situations. The goal of this series of reports is to attempt to make the job manageable. In doing so, the task of exposure assessment has been divided into the seven exposure settings listed previously (occupational, consumer, and so on). Methods and procedures were then developed or identified to aid assessment for each setting. Some of the methods apply to more than one setting, and some of the settings are related to one another or may be considered subcategories of others.

OTS performs a large number of exposure assessments in support of Sections 4, 5, and 6 of TSCA. This methods series is a collection of

information sources, generic data, and methods that are being used by OTS to perform exposure assessments efficiently and consistently. Other methods may be currently used effectively by other organizations; these OTS methods are not meant to automatically replace all other exposure assessment methods. Because of the large amount of information collected in these volumes, however, they are being published as a source of information for others doing exposure assessments. Other assessors may find this catalog of methods useful as a model to guard against significant oversights or omissions when performing their own assessments.

2. PLANNING AN EXPOSURE ASSESSMENT

Planning should be the first step of any complex task. This is certainly the case with exposure assessment, which can be bewilderingly complex unless one has a clear idea of the purpose, scope, depth, and approach to be used. This section discusses these four areas of planning an exposure assessment using concepts developed by Callahan (1982)*.

Every exposure assessment is based upon certain explicit or implicit assumptions. Limitations imposed by these assumptions affect the final form of the assessment and hence the comparability of different assessments. For example, one assessment may cover routes of exposure, such as ingestion of food, that another does not; one assessment may be 3 pages long, while another is 300 pages in length. Some simple arithmetic concerning the combinations of answers to the questions presented in this section show that there are easily hundreds of different ways to plan an exposure assessment, and hence many "different kinds" of assessments.

An exposure assessment cannot easily be regimented into a set format or protocol; there are many legitimate reasons for differences in purpose, scope, depth, and approach. Rather than in the format or protocol, the primary point of common understanding in exposure assessment must be in the use of a common set of questions to define the purpose, scope, depth, and approach, i.e., a common set of planning questions. By addressing these questions explicitly in the planning stage, the assessor will be better able to consolidate his approach and control the final form of the assessment. This will help save resources by eliminating unnecessary or unproductive work. It will also help the reader recognize the boundaries of the assessment and will facilitate comparison with other assessments.

---

*This section is abstracted from an unpublished presentation "Planning an Exposure Assessment", by M.A. Callahan, EPA-OTS-EED.

Preceding page blank

The planning of an exposure assessment actually comes down to a very manageable number of questions, which are discussed individually in the following subsections.

2.1 Purpose of Exposure Assessments

The purpose of an exposure assessment is often stated as its intended use, for example, "in support of Section 6 of TSCA." While this may be accurate, it is not a sufficient guide for planning the form or content of the assessment. The question of purpose should be: "What will be done with the assessment after it is finished?"

Most exposure assessments are done as part of a risk assessment. In risk assessment, the exposure levels found for individuals or populations will be combined with effects data (hazard, toxicology) to estimate risk. If the exposure assessment is going to be used in a risk assessment, this usually requires that a quantitative or semi-quantitative level of exposure be assigned to individuals or populations.

Some exposure assessments, especially in regulatory agencies, are also used as a risk reduction evaluation tool. In other words, one calculates the exposure as it exists today, and then imposes certain proposed or hypothetical "controls" or "actions" and uses the assessment to evaluate the effects of those actions on exposure levels (and, subsequently, risk levels). Exposure assessments can thereby become powerful tools for predicting consequences of a variety of optional actions.

The latter type of exposure assessment requires a very different approach than the former. In the former case, monitoring data alone (if they exist) may provide much of the needed information. In the latter case, an effort must be made to understand the causes of exposure in addition to collecting data. These considerations will arise in questions under "Approach," below.

A third purpose of an exposure assessment would be to answer the question of whether there is significant exposure, independent of a risk assessment. In this case, the exposure assessment is an end in itself. This purpose arises infrequently compared to the first two purposes. An example of such an exposure assessment would be that required by section 4(a)(1)(B) of TSCA, where the Agency is directed to require testing of a chemical based on substantial exposure.

In summary, it is important that the assessor clearly define the purpose of the assessment in the sense of "what will be done with the assessment when it is finished?" The answer(s) to this question will have a significant impact on the scope, depth, and approach, where the questions about "what is needed to accomplish the end purpose" and "how to get there" are addressed.

2.2 Scope

Scoping questions limit the broadness of the assessment. These questions, more than any other, determine the general outline of the exposure assessment. They also play a critical part in potential resource expenditure, since unclear answers to these questions may result in much unnecessary effort. Scoping questions are of the nature of, "What should be included or excluded from the assessment?" They need to be addressed as a group, rather than sequentially, since they are interrelated. Note that they do not address the detail in which the topics are covered, but merely whether they are to be covered at all. The question listed below also need to be thought of in the context of the hazard of concern, if it is known, which can serve to focus the assessment somewhat.

Humans vs. Non-humans

Should the assessment include exposures to humans only, non-humans only, or a combination of the two?

Individuals vs. Subpopulations vs. Populations

Should the assessment include all humans (if appropriate) in a defined area, or just some of them? For example, an assessment may cover everyone in the U.S. (population), only pipefitters (subpopulation), or only the pipefitters in a particular plant (several individuals). If non-humans are to be assessed, which species (populations) or other divisions (subpopulations) are to be considered?

Geographic Boundaries

Will this assessment cover people exposed to a certain plant or dump site (site-specific), a city or town (local), a state or similar area (regional), the entire country (national), or the world (global)? Although the same things must be addressed in each case, the approach to these assessments may need to differ widely from one another. One may also define the geographic boundaries as a series of sites, regions, etc., as when assessing "all the plants that make chemical Z," which may fall into three specific regions.

Route of Exposure

The route of exposure is the means by which the chemical or agent enters an organism. For humans, the normal routes are ingestion (e.g., food, drinking water), inhalation, and dermal absorption, although other routes are possible (direct contact with blood through an injury, medical treatment, etc.).An assessment may be limited to one or more of these routes.

Media

The exposure media are the vehicles that transport the chemical or agent to contact the receptor. These could include air, surface water, drinking water, food, or others. The assessment may be limited to the exposures occurring through certain media. This has often been the case with exposure assessments done in the past by regulatory groups with

authority over only one medium. More recently there has been a tendency to do more detailed assessments in a single medium, but also to do rudimentary assessments in other media in order to maintain perspective. (Remember, the scoping question asks only if the media are to be addressed, not in what depth). An assessment in a single medium may also want to consider sources in a different medium. For example, if one were hypothetically assessing air exposure to chemical A, one could also be interested in water discharges which result in air pollution (but not necessarily all water discharges) if one were planning to evaluate control strategies.

Exposure Settings

One of the common ways of limiting an exposure assessment is by limiting exposure settings. One can break out the total exposure to a chemical agent into several general categories for convenience. In the case of the seven settings that are the subjects of these methods reports, one can define boundaries around each setting and use these boundaries to limit the assessment. Although the seven settings are somewhat arbitrary, they do tend to allow exposures within each setting to be addressed independently from the others. Once the boundaries are established, subdividing exposure assessment into categories or settings provides both a structure for organizing the assessment and a framework for data collection.

One of the most common differences, if not the most common difference, among exposure assessments today is a difference in the exposure settings covered by the assessment. OSHA/NIOSH tend to be interested in the occupational setting only; CPSC concentrates on consumer use, FDA on food, and so on.

2.3 Depth

Another critical area in planning an exposure assessment is the depth of detail. This is another reason for diversity in exposure assessments

and why one assessment can be three pages long while another is 300 pages long.

Exposure assessments are usually used as support for decision making. How much effort is expended in refining the accuracy and detail of an assessment needs to be commensurate with the importance of the decision being made.

The overall question guiding the planning for how detailed the exposure assessment must be, after considering the importance of the decision to be made, is, "What degree of accuracy and precision is needed to make the decision?" The answer, "the most accurate degree possible" is usually not a good answer for at least two reasons. First, if the exposures are to be used in a risk assessment (and most are), the risk assessment will be no more accurate than the least accurate of the two components, hazard and exposure. It may be wasteful of resources to plan an exposure assessment which is orders-of-magnitude more accurate than the toxicological information with which it will be combined. On the other hand, one may want to be more detailed on the exposure side because the assessment will be used to evaluate control options. In any case, the matching of accuracy of the hazard and exposure data must be carefully considered.

Second, "the most accurate answer possible" is rarely the most accurate answer feasible. Once one reaches a given level of accuracy (i.e., plus or minus an order of magnitude; plus or minus a factor of two; etc.), additional improvements become far more resource-intensive. Although it is possible in many cases to improve the accuracy and precision of the assessment, one may run out of resources long before reaching the "most accurate assessment possible," with marginal additional benefits in the quality of decisions derived from the assessment.

Another consideration in planning for depth of detail is that the assessment need not have the same level of detail in all areas. For example, an assessor in EPA's Office of Water may want a detailed assessment of exposure through surface water. In addition, the assessor may want to put this waterborne exposure into perspective by comparing its magnitude with exposures through air, food, etc. The result would be a detailed assessment on water and a much less detailed estimate in the other exposure settings. This "mixed" level of detail is becoming increasingly common with the push toward multimedia exposure assessments.

Exposure assessments usually have five components: sources, fate, monitoring, populations, and integration (see Section 3). In planning the depth of detail, simplifying assumptions are often made in these components. For example, in doing an assessment on pollutants from vehicular exhaust, one can assume a number of vehicles, each with an average emission rate. One may then look in much more detail at the fate of the pollutant, or examine extensive monitoring data. On the other hand, one might do an extensive materials balance on the sources of a chemical in widespread use, and make certain simplifying assumptions about the populations exposed (e.g., all U.S. population exposed to some average level). Often the depth of detail in the five exposure components are dictated by resource limitations and lack of data. (The components themselves will be discussed in more detail in Section 3.)

2.4 Approach

The answers to the scope and depth questions above have a large influence on the approach taken. The exposure assessment field has many useful tools, and in planning an approach, one is deciding which tools to use. The following questions are useful in directing the assessor to the proper tools.

- Will this assessment be qualitative ("is there exposure or not?"), semi-quantitative ("are exposure levels high or low?"), or quantitative

("what is the exposure level?")? The answer will be especially influenced by how purpose and depth are defined.

- What mix of measurement techniques vs. predictive/theoretical techniques is desired? A purely measurement-oriented assessment would involve measuring the exposures to each of the members of a population (or some statistically representative subset) over a period of time. While this practice may sometimes be feasible, it is usually expensive due to sampling and analysis costs. A purely measurement-oriented assessment also may not allow geographic interpolation between data points, which can be a drawback in complicated exposure distributions.

  A purely predictive/theoretical assessment, on the other hand, involves modeling and predicting of exposures on a theoretical or empirical basis. This type of exposure assessment may be much less expensive than one using monitoring, but may yield results that are widely at variance with actual exposures. However, this approach does provide a basis for understanding how a chemical behaves and how the exposure is taking place.

  Neither pure technique is used very often; rather, a mix of monitoring data and predictive tools are usually used. In planning the assessment, the considerations here are resources available (lower resources drive the assessment toward predictive techniques or more narrow scope), and accuracy of exposure required (more accurate assessments require a greater mix of monitoring as a verification of the predictive tools).

- What period of exposure is to be covered? An assessment of carcinogenic risk often considers exposure over 70-year lifetimes, but the toxicological information may dictate the need for yearly exposures, daily exposures, hourly exposures, or even continuous exposures. The answer to this question should reflect a match between the exposure and hazard information.

• How should exposure be defined for the purposes of this assessment? Generally, "exposure" has been viewed at least three different ways in past assessments. First, some assessments look only at concentrations of a chemical or agent in the media of concern. This approach requires a set of assumptions (e.g., breathing rates, or food intake rates) if an actual exposure assessment is to be made, since without considering populations, no exposure can be evaluated. Second, many assessments look at the contact between the chemical and the individual with such concerns as how it is ingested, applied to skin, or inhaled. This is a very common treatment of exposure, and matches much of the animal toxicology studies where a dose-response curve is set up in terms of inhaled amount vs. effect or ingested amount vs. effect or amount rubbed on skin vs. effect. A third way of treating exposure is to look at absorbed dose, such as amount <u>absorbed</u> through dermal contact, ingestion, or inhalation. More recently the "absorbed dose" treatment of exposure has been gaining popularity, mainly due to additional information and understanding which can be added to the assessment.

• What types of scenarios will be set up? Scenarios are tools to estimate exposure levels when conditions are those listed in the scenario's assumptions. Conditions, however, may change significantly so that in the actual situation, a given scenario only applies for a part of the time. Is this assessment looking at "worst-case" scenarios? These are good for determining when exposure (risk) is <u>not</u> a problem, but not for determining the extent of a problem if one does exist. "Reasonable worst case" scenarios look at the worst case that is likely to occur with a frequency that would cause concern. "Typical" case scenarios depict average or widespread conditions. One may also want to view the likely range of exposures, or even the distribution of exposures over a population (the latter is particularly resource-intensive). The scenarios one chooses are dependent on the purpose, scope, and depth questions.

- Is the assessment concerned with a single chemical, a number of chemicals, or a mixture or other substance? The tools one chooses to perform the risk assessment will vary, sometimes widely, according to the answer to this question.

2.5 Summary

Planning is a critical step in preparation of an exposure assessment. Planning involves answering a relatively small number of specific questions on purpose, scope, depth, and approach. Once the purpose, scope, depth, and approach are defined, the assessor will have a much better idea of the tools needed to do the work. If the planning assumptions, decisions, and definitions are clearly stated in the exposure assessment, the reader will be able to quickly determine what type of assessment it is, what is included, and whether it is likely to meet his or her needs.

3. ORGANIZATION AND CONTENTS OF AN EXPOSURE ASSESSMENT

A suggested outline for an exposure assessment document is given in Table 1. The actual order in which topics appear is somewhat arbitrary. However, the document most often includes some discussion of all five major topics listed below and proceeds in a logical order from sources to exposure estimates.

The major topics that are usually addressed are: sources, fate and pathways, exposed populations, monitoring (or estimated concentrations), and integrated exposure analysis. Examples of subheadings within each of these topics are presented in Table 1. The extent to which any assessment discusses these subtopics depends on the purpose, scope, and depth of the assessment as well as on the quantity and quality of available information. A given topic may be covered by a single statement proposing a broad assumption, or by a detailed analysis of each piece of information. The outline is simply a guide for organizing whatever data are developed for each assessment. In its general structure, this outline is appropriate for assessments of any scope (including site-specific assessments) or depth (including screening level assessments), and for both new and existing chemicals.

The sections from "Sources" through "Monitoring" may each have several subsections for each setting or for each chemical of a multi-chemical (e.g., industry-wide or site-specific) assessment. The different settings are combined in the "Integrated Exposure Analysis" section.

The components of an exposure assessment report will be described below, based on recommendations in EPA's Interim Guidance for Exposure Assessment (USEPA 1984)* ; consult this guidance, published in the Federal Register (November 23, 1984), for more detailed information.

---

*This section is abstracted and adapted from the EPA's proposed guidelines (49FR227:46304).

Table 1

SUGGESTED OUTLINE FOR AN EXPOSURE ASSESSMENT

1. EXECUTIVE SUMMARY

2. INTRODUCTION
   - 2.1 Background
   - 2.2 Purpose and Scope

3. GENERAL INFORMATION
   - 3.1 Identity
     - Molecular formula and structure, CAS number, TSL number
     - Description of technical grades, contaminants, additives
     - Other identifying characteristics
   - 3.2 Chemical and Physical Properties

4. SOURCES
   - 4.1 Production and Distribution
     - Production quantities and process
     - Distribution in commerce
   - 4.2 Uses
   - 4.3 Disposal
   - 4.4 Summary of Environmental Releases

5. EXPOSURE PATHWAYS AND ENVIRONMENTAL FATE
   - 5.1 Transport and Transformation
   - 5.2 Identification of Principal Pathways of Exposure

6. MONITORING OR ESTIMATED CONCENTRATIONS
   - 6.1 Summary of Monitoring Data
   - 6.2 Estimation of Environmental Concentrations

7. EXPOSED POPULATIONS
   - 7.1 Human Populations (Size, Location, and Habits)
     - Population size and characteristics
     - Population location
     - Population habits
     - (often arranged by the seven exposure categories in Table 2)
   - 7.2 Non-human Populations (where appropriate)
     - Population size and characteristics
     - Population location
     - Population habits

8. INTEGRATED EXPOSURE ANALYSIS
   - 8.1 Development of Exposure Profiles
     - Identification and characterization of the exposed populations and critical elements of the ecosystem
     - Pathways of exposure
   - 8.2 Human Dosimetry and Monitoring
   - 8.3 Calculation of Exposures
   - 8.4 Evaluation of Uncertainty

Source: Adapted from USEPA (1984)

3.1 General Information

This section should contain background information on the chemical(s). Each chemical should be identified by at least the following characteristics (where appropriate): molecular formula and structure; synonyms; Chemical Abstracts Service (CAS) number; description of technical grade, contaminants, and additives; and radioactive halflife (if applicable). Chemical and physical properties should be summarized, emphasizing those features that affect the chemical's behavior in the environment. These properties may include molecular weight, density, boiling point, melting point, vapor pressure, water solubility, vapor density, partition coefficients, and chemical halflife, among others.

Data may be obtained by following the procedures described in Volume 2. Therefore, an assessor may wish to consult Volume 2 even when preparing an assessment that excludes the ambient scenario.

3.2 Sources

Any points at which the chemical may enter the environment should be identified in this section, together with any known or estimated rates of entry. A detailed exposure assessment will include or be based on a previous "materials balance". A materials balance is a study of sources, production, uses, destruction/disposal, and environmental release of a substance which quantifies the mass made, incorporated into products, and lost to the environment.

The source chapter as a whole will consist of information derived from Volumes 2, 3, 6, 7, and 9 of this series. In the sources section, the quantities of the chemical released to each environmental medium should be estimated as best as possible. An extremely detailed assessment may attempt to specify the following for each significant source: location, quantity of the chemical released to each medium as a function of time, physical characteristics of the source, and the

physical and chemical form of the substance being released. The assessor should evaluate the level of uncertainty associated with the estimates and remain aware of uncertainties through the rest of the exposure assessment.

3.3 Exposure Pathways and Environmental Fate

This section should describe how the chemical gets from the source to the receptor population. Broad generalizations on environmental fate may suffice for less detailed assessments. In the absence of data, as for new (PMN) substances, fate may be predicted by reference to data on analogous substances. Fate may also be predicted using models or experimental data. At any level of detail, a given pathway may be judged insignificant and excluded from further consideration. Pathways, sites, and media may also be limited by initial scoping decisions.

For more detailed assessments involving environmental fate, the source analysis described above should provide not only the rate of emissions but the location of emission sources. Fate analysis tracks the substance from its initial point of release through the environment to its ultimate fate. It may provide an estimate of its geographic concentration distribution and changes in levels with time within the media of concern.

Guidance in performing the fate analysis may be found in Volume 2. Volume 6 and Volume 5 discuss models of particular relevance to assessments of occupational and drinking water exposure respectively; both, however, refer back to Volume 2 for necessary background information.

The fate chapter includes discussions of the following:

- Transport and transformation. It is essential to evaluate the environmental behavior of a substance, since chemical and physical processes may yield an ultimate environmental distribution quite different from the initial distribution at the point of release.

-- Transport includes hydrological, atmospheric, or other physical processes that convey the mass of a pollutant through and across media from source to receptor. They may also serve to concentrate or dilute the pollutant.

-- Transformation is the chemical alteration on a compound by processes such as biodegradation, hydrolysis, photodegradation, reaction with other compounds, etc.

- Environmental partitioning. Models may be used to estimate relative concentrations of a substance in difference environmental media.

- Identification of principal pathways of exposure. Once the environmental media containing the chemical are identified, potential pathways of exposure can be listed. Significant pathways are often defined by the chemical's load into a medium and its physical and chemical properties.

3.4 Monitoring or Estimated Concentrations

Monitoring data are used throughout the exposure assessment to estimate releases and environmental concentrations. These data should be evaluated for accuracy, precision, and representativeness. Evaluating, selecting, and interpreting monitoring data for each scenario are discussed in the corresponding methods volume. Unless environmental monitoring data are known to be complete and accurate, concentrations are often estimated as well, either by models or by analogy with better-known chemicals.

Concentration estimates should be compared (when possible) with monitoring data. However, one must keep in mind that monitoring data are often not comparable to modeling results. For example, measured atmospheric concentrations usually represent instantaneous or short-term average levels (e.g., over several days or weeks), whereas models may predict annual averages at different locations. Therefore, great care must be exercised when comparing estimates with monitoring data. Monitoring data should not be considered a de facto substitute for environmental pathways and fate analysis, at least in the following situations:

- when monitoring data are limited in scope;
- when analysis of monitoring data alone sheds little light on the relationships between materials balance data and ultimate environmental concentration distributions; or
- when fate analysis is required to trace measured concentrations back to individual sources that can be regulated.

Environmental concentration estimates should be presented in a format consistent with the purpose and depth of the assessment. An estimate of annual average concentration may be sufficient for a general assessment. More detailed assessments may require an estimate of the temporal and geographic concentration distribution. It may also be useful, if regulatory options are being analyzed, to project future environmental concentrations resulting from controlled releases.

3.5 Exposed Populations

Populations to be studied may be defined at the outset of the assessment, or else selected later on the basis of sources and fate studies. Subpopulations of high sensitivity may be studied separately. Subpopulations may be defined on the basis of geographical area, age, sex, etc. For example, one may wish to enumerate women of child-bearing age if the chemical is a known or suspected teratogen.

Guidance in identifying exposed populations within each exposure setting may be found in the "Exposed Populations" section of the appropriate methods volume. Enumeration and characterization of all populations is discussed in Volume 4.

3.6 Integrated Exposure Analysis

In this section, estimates of environmental concentrations are combined with data on exposed populations to yield exposure profiles and pathway analyses. This entails integrating the settings for a total exposure picture (assuming the scope of the assessment includes more than one scenario).

A population may be exposed to a chemical from several different sources and through several exposure routes. Ideally, total exposure for a population is determined by summing exposures from all sources within an exposure route. In reality, exposures are usually not summed because (1) it is not known, for example, whether the people exposed occupationally are the same as those who are exposed via drinking water, and (2) EPA's regulatory purposes require separate estimates. Exposures through different routes are usually kept separate for at least the following reasons:

- Different exposure routes are often associated with different rates of absorption and different types of toxicity;
- Target organs may differ;
- Keeping routes separate will facilitate formulation and evaluation of control options.

Exposure estimates may be compared with results of any available human dosimetry, personal monitoring, or body burden analyses.

Exposure calculations and results should be presented in a format consistent with available dose-response data in order to facilitate ultimate risk assessment. For example, results can be expressed as annual average exposures, peak exposures, exposures in excess of a given threshold value, etc.

An integrated analysis should include the size of the exposed population; duration, frequency, and intensity of exposure; and route of exposure. Exposures should be related to source, since it is ultimately sources that are regulated. The assessor should also evaluate the associated level of uncertainty by analyzing the uncertainties in each step of the assessment.

More detailed assessments may consider such factors as the geographic distribution of receptor populations, or their relevant behavioral and biological characteristics. Scenarios may be constructed to illustrate exposure via multiple settings; for example, a worker who lives near a

plant and is exposed occupationally, by breathing ambient air, and by drinking contaminated water. Subpopulations exposed to different concentration ranges may be enumerated separately. Results may be presented in tabular or graphic form.

It can be seen that the form and contents of the "Integrated Exposure Analysis" section depend on the purpose of the assessment and on other considerations discussed in Section 2 of this volume. The individual methods volumes do not provide specific guidance on this subject. Section 5 of this volume does provide examples of assessments with various levels of detail. However, two different assessments of the same general type may still require slightly different treatment. Each assessment will have a unique set of problems which must be solved on a case-by-case basis, and it is not possible to provide detailed rules for dealing with every conceivable alternative.

4. OVERVIEW AND INTEGRATION OF SETTINGS

Each of the seven settings in which exposure may occur is the subject of an individual volume in this methods series. An additional volume discusses the populations exposed in each setting. Recall that the division between settings, as defined below, is largely for the sake of convenience:

- ambient exposure
- exposure resulting from disposal
- occupational exposure
- exposure resulting from transportation spills
- exposure from ingestion of drinking water
- consumer exposure
- exposure from ingestion of food

This section summarizes the contents of each volume. The subject matter in the methods series may be seen in Table 2, which lists the major data needs in each exposure setting. To avoid redundancy, some data needs common to all settings (such as chemical properties) is addressed only in one volume, and the reader is referred between reports as necessary.

4.1 Exposure to Chemical Substances in the Ambient Environment

Volume 2 of this series describes methods for assessing exposure of humans (and, to a lesser extent, non-humans) to chemicals in the ambient environment. In this case, the ambient environment refers primarily to outside air and surface waters. Ambient exposure is unique in that individuals are exposed to chemicals simply in the normal course of their daily routine, rather than as a direct consequence of their activities (occupation, use of a product, etc.). In other words, the exposed populations have little or no choice or control over their exposure. The chemicals are in the ambient environment as a result of someone else's activities. Estimating exposure in this environment can be difficult because the presence of a chemical may be a result of a large number of activities (i.e., production, various uses, etc.). This is further complicated by the

Table 2. Exposure Assessment Needs for Various Exposure Settings (Adapted from USEPA (1984))

Exposure Setting	Sources Needs	Fate Needs	Population Needs	Monitoring Needs
Occupational	Site/plant locations; in-plant/on-site materials balance; industrial and commercial uses; trade patterns	Chemical properties and intermedia transfer models	Numbers and categories of workers; age and sex	In-plant/on-site levels; personal & body burden monitoring
Consumer	Uses, concentration in product, consumption rates and patterns	Chemical properties, release rates, intermedia transfer models	Numbers of users of consumer products; age and sex	Levels in products, releases
Transportation Spills	Patterns of distribution & transportation; spill frequency	Chemical properties, environmental fate models	Number and characteristics of storage, transportation and cleanup-workers; general population in area	Releases, ambient levels following incidents
Disposal	Materials balance for disposal method, with releases to environment	Effect of treatment/disposal method; environmental fate of releases	Size of general population around sites; age, sex	Releases from each treatment/disposal method; ambient levels
Drinking Water	Output of ambient and/or disposal methodology; treatment & distribution system	Aquatic fate; chemical effects of treatment process	Location and size of general population; age and sex	Levels in drinking water, ground water, surface water, and at treatment plants
Ambient	Site/plant locations and production volumes; materials balance, emissions factors, or source monitoring	Chemical properties, environmental fate models	Number, characteristics and location of general population; nonhuman populations	Ambient air and water; personal and body burden monitoring

transport and transformation processes that occur in the environment following a chemical's release.

As discussed in Section 2, exposure assessments can be performed for several purposes. Among the most common are to determine the risk posed by the chemical and to identify possible methods to reduce the risks. There are many tools, techniques, and information sources available to help an assessor accomplish either or both of these purposes. Some of the most useful of these are described in Volume 2 of this series.

The tools and techniques described in Volume 2 include estimation techniques, mathematical models, and monitoring data. Each has strengths and weaknesses. Volume 2 describes the specific limitations and provides guidance on the appropriate use of each tool. The tools used together (when appropriate) may help present a more complete picture of exposure.

The most significant routes of exposure described in Volume 2 are inhalation of ambient air and dermal contact via swimming in contaminated surface waters. Calculation of inhalation exposure involves combining the air concentration, breathing rates, frequency, and duration of exposure. This results in an estimate of the quantity of chemical taken into the lungs. If information is available on the rate at which the chemical is absorbed through the lung tissue, this can be used to calculate the dose, or the quantity taken into the body. However, this type of information is usually not available. Therefore, it is important that the assessor be aware of this and understand that neglecting the absorption rate may cause calculated exposures to be somewhat higher than the amount actually taken into the body. Toxicological data often take absorption into account; if that is the case for the chemical substance being assessed, and the exposure assessment is in support of a risk assessment, no attempt to quanitify absorption need be made.

Dermal exposure in the ambient environment can be somewhat more

difficult to quantify. For inhalation, a known volume of material is taken into the lungs. This volume is used to determine the exposure levels. However, when all or part of the body is immersed in contaminated water (as may be the case while swimming), it is very difficult to determine the quantity of material which a person contacts. Under these circumstances, the following factors determine exposure:

- ambient concentration
- area of skin exposed
- frequency and duration of exposure
- diffusion rate of chemical through the skin

Calculation of aquatic concentrations is relatively straightforward, and can be used to assess ecosystem exposure as well as human exposure. Unfortunately, information on diffusion rates of most chemicals through skin are not available. However, methods have been developed that allow this to be estimated for many substances. Although a detailed description of these methods is beyond the scope of this report, Volume 2 shows where this information may be found.

As an alternative, assumptions may be made regarding the quantity of chemical in contact with the skin. These assumptions involve estimating the thickness of the layer of material on the skin and the surface area of skin exposed. This information can be used to determine the volume of material on the skin. Multiplying this by the density of the material yields a quantity of material on the skin. More guidance on doing this is provided in Volume 2.

Much of Volume 2 involves discussion of methods to calculate the concentration of chemicals in the air and water. The use of models such as UNAMAP and ATM for estimating ambient air concentrations and EXAMS for water concentrations is described. The report goes on to describe how these model outputs are used in the exposure assessment process.

The use of monitoring data is also described in the report. These data represent measured concentrations of a chemical at a specific location at a particular time. They must be used with caution, as described in the report. Sources of this information include a number of computerized data bases maintained by several agencies of the U.S. Government. Some of the data bases described include AEROS and SAROAD for air data and STORET for water, sediment, and biotic data.

The report also includes information for determining activity patterns of exposure populations. This information is used to define the frequency and duration of exposure. The activity patterns show how often an individual is located in a contaminated environment and for how long. Volume 2 also provides some guidance on estimating the size of the exposed population. A more complete discussion of this can be found in Volume 4.

Estimating ecosystem exposure (i.e., exposure of non-human populations) is very similar to the process described above, as far as estimating environmental concentrations. Population characteristics such as size, frequency and duration at the exposure site, and inhalation rates are usually unavailable (or often irrelevant). However, Volume 4 of this series describes some of the sources of this type of information.

4.2 Exposure from Disposal of Chemical Substances

Volume 3 of the exposure assessment methods series presents methods for assessing exposures resulting from disposal of chemicals. These exposures result from releases of the chemical into the ambient environment; this report guides the user in estimating the magnitude and frequency of these releases. The user is then referred to the ambient exposure methods volume to estimate the resultant concentration in the environment and subsequent exposure, or to the drinking water methods report if releases to water are expected as a result of the disposal methods.

This report on assessing exposures relating to disposal is essentially a mass-balance technique. The six most common disposal methods are addressed: landfilling, land treatment, surface impoundment, incineration, sewage treatment, and injection into deep wells. A series of decision trees guides the user through the steps of the technique, and at each step where data are required, the potential sources of the data are listed. A great deal of data that apply to a disposal method or pattern, regardless of the chemical substance being disposed of, are also presented.

This methods report is arranged in a fashion unlike the others; the framework is a series of stages. There are five stages, as described below:

- Stage 1 takes a basic materials balance and determines the total amount of waste to be disposed of from each manufacturing process or end use.
- Stage 2 lists the individual wastestreams for which data have been compiled.
- Stage 3 allocates the wastestreams to the most likely disposal method of the six listed above.
- Stage 4 allows one to determine the geographic distribution of treatment sites.
- Stage 5 estimates emissions from disposal; when disposal results in additional waste (like incinerator ash), the method allows for that waste to be dealt with in Stage 3 and subsequently.

Accurately assessing exposures resulting from disposal practices requires information on the location of waste production and the location of waste disposal. This report leads the user to sources of such data on the state, local, regional, and national level. Often, however, these data will not be adequate; this subject is one for which generic national data have been developed.

This methods report is geared to a very detailed assessment of disposal related exposures. In many cases, the procedure requires that

loops through the framework be repeated a number of times. Such is the case if a chemical may be disposed by more than one of the six methods (a common occurrence), or if a treatment scheme generates a new waste to be disposed of. The report does, however, present guidance in simplifying the assessment. Methods for determining which treatment modes may be relatively insignificant (and thus disregarded) and a number of other simplifying procedures are discussed. The circumstances under which an assessment is best made qualitative or semi-qualitative are briefly addressed.

4.3 Populations Exposed to Chemical Substances

The fourth volume in this series is the report on enumerating and characterizing the populations exposed to chemical substances in each of the seven exposure settings. As in the other reports, a great many methods are presented that may depend either on generic data included in the report or on sources of specific data that the reader can be directed to. Unlike the other methods volumes, however, the methods are presented as a series of steps to be performed; more guidance is provided in choice of methods as well.

The first chapter in this report is an extensive discussion on quantifying and characterizing populations exposed to chemical substances in the ambient environment. Most of the methods rely on data collected by the Bureau of the Census, regardless of the source of the chemical in the environment. Recall that the distinction between the sources discussed in the ambient, transportation spills, and disposal exposure reports is a somewhat arbitrary one used largely for organizational purposes in these reports. This chapter, though titled Populations Exposed in the Ambient Environment, deals with all three types of sources.

Choosing the best method for enumerating a population exposed in the ambient environment depends not only on the route of exposure but also on

the characteristics of the chemical source. Different methods apply to point sources, area sources, and line sources and the methods may differ according to the number of similar sources to be dealt with. A point source release is easily defined, and its position can be accurately determined; the population consequently exposed is described in terms of distance from the source. The report discusses the use of a program called SECPOP, part of EPA-OTS' computerized GEMS system. SECPOP uses data from the Census Bureau to accurately perform population enumeration, along with an atmospheric dispersion/exposure model (ATM) if desired. Generic data are provided for use in exposure assessments that cannot, for any reason, deal with individually-defined point sources.

Area sources are usually much more numerous within any geographically-defined area and are therefore dealt with on a non-source specific basis. This report guides the user to the appropriate Census information methods that rely on population densities along with source densities to estimate exposed populations.

Line sources are often associated with transportation emissions, either from spills or releases of exhaust. The exposed population may therefore live along a corridor: a road or rail line. Populations may also be exposed at corridors along a river from which a chemical is volatilizing. Both site-specific methods that use actual Census data for a locale and methods based on generic population densities are presented.

The methods discussed above are for inhalation exposures, the primary topic of interest in ambient exposure assessments. Other types of exposures that can be important are dermal contact with waterborne pollutants during recreation and more incidental exposures like pica, the child's habit of eating dirt. These potentially exposed populations receive less attention in this report.

Some exposure assessments require that the exposed populations be exceptionally well-defined. The methods report on populations presents

age and sex distributions for the U.S. as a whole and lists Census publications that go to various levels of geographic resolution with such data.

The second chapter of the populations report presents methods to deal with occupationally-exposed populations. The preferred methods use data from the Bureau of Labor Statistics (part of the Department of Labor) and the Commerce Department's series of census reports - the Census of Manufactures, Censuses of Retail and Wholesale Trade, etc. The methods are presented step by step, with guidance in choosing the most appropriate method in each case. A small section is devoted to finding site-specific data when a limited number of manufacturing facilities are of interest. The final portion of the report guides the user in determining the age and sex distribution of an occupational group.

Populations exposed via food ingestion are the subject of the next chapter. The methods are keyed to the source of contaminant: agricultural practices, processing or packaging, other sources, and unknown sources (when contamination is demonstrated by monitoring data). Data from national surveys of food consumption, such as those performed by the USDA, are referred to throughout and are the basis of the methods to characterize the exposed populations.

Persons using consumer products containing chemicals for which exposure assessments may be required can be enumerated and characterized by the methods in the next chapter of this volume. The primary source of data is market research reports, such as the Simmons Market Research Bureau studies. They present data not only on the number of users of numerous types of consumer products but also on frequency of use and demographic characteristics of users. Though use of marketing data probably serve the majority of exposed assessment needs in this setting, supplemental methods are presented for predicting exposed populations from production data, use data, and from data on common hobby activities.

The final major section deals with populations exposed via the consumption of drinking water. Data maintained by EPA are the basis for most of the methods. One method relies on EPA files like the HLDF and the WSDB; user access to those files is explained and contact persons within EPA are listed. Also discussed are data needed to enumerate persons exposed to chemicals that may be introduced by a treatment practice or in the distribution system. It may be necessary to extrapolate results of monitoring that do not specify a contamination source to estimate populations exposed nationally, so an estimation procedure is provided to fulfill that need.

The final part of Volume 4 is an appendix illustrating the application of each method presented.

4.4 Exposure to Chemical Substances in Drinking Water

Methods for assessing exposure to chemical substances in drinking water are discussed in Volume 5 of this series. Only exposure derived from ingestion of the water is addressed in detail; exposure that may occur as a result of bathing or other dermal contact, or inhalation of chemicals that volatilize from drinking water, are only briefly discussed.

This methods report is linked by logic to the methods volumes that deal with quantifying chemical concentrations in surface and groundwater: the ambient, disposal, and transportation spills methods reports. This volume assumes that the exposure assessor has one of the following components with which to begin:

- The site of release of the chemical to the environment and sufficient information to predict the concentration.
- One or more measurements of the concentration in the drinking water (either before or after treatment).

The assessment proceeds upon paths defined by the type of data available-suggestive evidence resulting from the presence of nearby sources, or

positive evidence of contamination as shown by monitoring, whether or not the source is readily determined.

Exposure to chemicals via drinking water involves the major exposure route not yet discussed in this section of this report: ingestion. The framework for that exposure calculation is very straightforward. Exposure is a function of the concentration of chemical in water and the ingestion rate. The methods report discusses how to best assign values to each of these parameters.

The report begins with an overview of drinking water systems, including the characteristics basic to all as well as some specific differences between treatment plants that produce water from groundwater versus surface water sources. The sections that follow that overview are keyed to taking a release and turning it into a concentration at a raw water intake. Numerous models are discussed; the application of the most commonly-used models (like SESOIL and EXAMS) is emphasized. Also included is a fairly detailed discussion of the use of data bases maintained by EPA, such as HLDF. Those useful sources of information enable the exposure assessor to perform tasks systematically and effectively, such as determining the spatial orientation of suspected sources of drinking water contamination and potentially affected drinking water treatment plants.

A relatively large portion of the volume on drinking water deals with estimating the removal effectiveness of various water treatment schemes. Both treatment on a large scale, in a municipal system, and the effects of home treatments, such as water softeners and filters, are discussed. The report summarizes the most pertinent literature and translates much of it into readily-applied removal factors. Within that section is guidance in predicting the type of treatment expected for a particular source of water. Exposure may also result from addition of chemicals during treatment or distribution through pipes, either intentionally or as a result of a reaction between a trace contaminant in the water and a

chemical added during treatment (notably chlorinated organics formed as a result of chlorination). Techniques to predict the chemistry and fate of substances during drinking water treatment are presented.

As in many of the other assessment methods volumes, a brief section addresses the identification and enumeration of populations exposed to chemical substances in drinking water. Most of the methods discussed rely on data maintained by EPA and kept in files such as the Water Supply Data Base and the Federal Reporting Data System. Generic data that can be used to predict the populations exposed as a result of treatment practices themselves are presented; they are based on such factors as the national use of various types of water treatment chemicals and the relative amount of water drawn from surface and groundwater. The details of assessing population exposure are in the Volume 4 report on populations.

The exposure calculation procedure is the subject of the final section. The commonly-used intake factor is supplemented with a listing of water intake rates by age and sex of the individual.

4.5 Occupational Exposure

Volume 6 describes methods for assessing exposure in the workplace. Inhalation and dermal contact are the most important routes of exposure in that setting, and they are the only ones considered in this volume. The basic methods and data needs for dealing with inhalation exposure in the occupational setting are very similar to those discussed previously for the ambient environment. Dermal exposure is significantly different in that, unlike the dilute concentrations of contaminant encountered in the ambient environment, dermal exposure in the workplace usually means contact with a concentrated industrial waste stream or handling the chemical itself.

There are a variety of sources of chemical exposure in the workplace, most of which are best described by the type of operation being performed: manufacturing of the chemical, production of intermediate or final products, commercial use, sales, or other operations. Volume 6 discusses many of the specific activities that are expected to lead to worker exposure.

Though the terms "pathways" and "fate" are commonly construed as a set of processes that occurs outdoors, in air or water, some transport and transformation of a chemical also occurs in the occupational environment. This report discusses the fate processes that are likely to affect worker exposure to chemical substances indoors: the characteristics of the chemical that define its fate indoors are also discussed, with reference materials for obtaining chemical property information presented with estimation techniques for use when data are unavailable.

A quantitative exposure assessment requires, by definition, some knowledge of the concentration of the chemical; in this case, in the indoor work environment. The concentration can be estimated by using models that incorporate release amounts and fate process information. This report provides guidance in selecting and applying predictive models to describe worker exposure.

Monitoring data are often available (through regulatory agencies like OSHA and NIOSH or from chemical manufacturers themselves) that can be used to quantify exposure. In some cases, when data are plentiful and appear valid, they may form the basis of the assessment. In other cases, the monitoring data may be used in conjunction with model predictions to provide estimates of long-term average worker exposure. The occupational exposure methods report guides the user in obtaining relevant monitoring data and then assessing the data for validity and applicability. The sorts of questions the report leads the reader to ask about data are:

- Are the measurement techniques correct?
- Were a sufficient number of samples taken so that the data are representative?
- Are the data reported as short-term or long-term averages?

As with all the scenario-based methods reports, there is a brief discussion of identifying, quantifying, and describing the potentially exposed populations. The details of that subject comprise a section in Volume 4. This report simply describes the types of employment data available from the Bureau of Labor Statistics, the Department of Commerce, and other agencies and organizations. The format of the data are described relative to the needs of an exposure assessor and guidance for matching the two provided as needed.

There are two appendices to this report that bear mentioning. The first is a compilation of data on expected release amounts and characteristics. This appendix is very detailed; there are 23 chapters with titles such as Chlorination, Hydrolysis, and similar unit process descriptors.

The second appendix is a matrix of information sources, followed by pages from each referenced book, data base, or journal publication. A similar appendix was also prepared for many of the other methods volumes.

4.6 Consumer Exposure

The seventh volume in the exposure assessment methods series presents methods for assessing exposure resulting from use of consumer products. Inhalation and dermal contact are the routes of most interest in this setting; as in the other volumes, methods for fulfilling the data needs for exposure calculations are the bulk of the report. Not considered in this report are consumer products and consequent exposures that are not under EPA's regulatory jurisdiction: foods, drugs, commercial pesticides, tobacco, firearms and explosives, and a few other

categories. The difference between active exposure, which occurs while a person actually uses a product, and passive exposure that can be experienced afterward or by bystanders, is noted; there are some ramifications in calculation of exposure that depend on whether it is an active or passive process.

Following the introduction, this report lists the chemical properties most important to a consumer exposure assessment. Sources of data and some general information are listed.

The most significant limitation to assessments of exposure to chemicals in consumer products has in the past been defining the formulation of the product. Such data are carefully guarded as proprietary; only imprecise information provided for poison control and similar applications has been available. This methods report lists sources of pertinent information, and summarizes formulary data for twenty common household products in an appendix.

The amount of chemical released as a result of use can range from nearly 100 percent, as in the case of aerosol sprays, to a small fraction quantifiable only through use of complex migration equations. The full gamut of releases is addressed, and simplified release models are presented for use in assessments when time is limited or results are primarily for screening purposes. The methods presented serve as input to calculations of indoor air contaminant levels, which are usually the only available way of estimating inhalation exposures (monitoring data are especially rare in this setting). Other data needed for that exposure estimate, such as room volume, are also presented.

A summary of the methods to identify, enumerate, and characterize exposed populations comprises the next section. As in the entire methods series, detailed information is not presented; the user is referred to Volume 4.

The final section of the report explains the complete logic and calculation train of a consumer exposure assessment. Frameworks for

calculating inhalation and dermal exposure are discussed and some data on incidental pathways that may occasionally be significant are presented. The information on inhalation exposure calculation is much like that presented in the other assessment methods volumes. The information on dermal exposure estimation is more detailed than that contained in the volumes for other settings in which dermal exposure may occur (the ambient and occupational environments). Those data on skin surface area, thickness of films remaining on the skin after contact with a solution, and dust adhesion factors are applicable to the ambient and occupational settings as well.

The final sections of this volume are appendices that illustrate the methods outlined throughout; valuable additional data are presented and exposure scenarios for many consumer product uses are set up. Information resources summaries comprise the last appendices.

4.7 Environmental Pathways of Food Contamination

Exposure to ingested chemicals is the product of the amount of (in this case) food ingested and the concentration of chemical substance in the food. This report concentrates on identifying pathways by which food can become contaminated and presenting methods to estimate levels of chemical contaminants in foods. The report also discusses calculation of total dietary intake of contaminants.

Following the introductory material, which includes an overview of the methods and the framework in which they are presented, a discussion of pathways by which foods may come into contact with and become contaminated with chemicals is presented. A chemical's uses, its physical chemical properties, and the nature of the food itself are the major determinants of pathways of contamination. For any exposure assessment, the assessor can perform a systematic evaluation of the likelihood of food contamination with the use of this list. A scoring exercise that takes into account both the magnitude and severity of potential contamination is then presented; use of the scoring will prioritize pathways for quantitative treatment.

Two approaches to food exposure evaluation are discussed. The approach that comprises the bulk of this methods volume is geared toward predicting the level of food contamination resulting from each pathway; this approach is necessary when no monitoring data are available or when the assessor must be able to relate particular sources of contamination to the presence of a chemical in food. The use of monitoring data alone to calculate exposure is more straightforward. Predictive methods to estimate the level of the chemical substance in a food are presented in these groups of pathways:

- Bioconcentration by livestock or fish of chemicals in their environment or food;
- Uptake by crops;
- Post-harvest contamination (storage or processing in the presence of a contaminant);
- Direct addition (including inadvertent addition, such as in process water).

Brief examples of methods applications are presented throughout. A discussion of potential loss of pollutant during consumer preparations, such as washing and cooking, completes that portion of the methods report. Though not quantitative, a similar subject briefly dealt with is accidental contamination of food.

The final portion of this volume summarizes the methods and provides example calculations for a variety of scenarios, often combining methods dealing with different pathways of food contamination.

4.8 Exposure from Transportation-Related Spills

Methods for assessing exposures from transportation-related spills are presented in the ninth volume of this series. Much like the disposal exposure methods report, this is not a stand-alone report but one that is to be used in conjunction with the ambient and drinking water exposure

methods reports. This report presents information on tracking the routes along which chemicals are transported and discusses some methods for predicting the volume and frequency of spills from three types of transportation: trucking, rail, and barges.

The heart of the report is an adaptation of probability theory that allows the assessor to rapidly apply accident statistics and chemical-specific information to estimate spill releases. Methods are presented in the report to assign values to each of the parameters in the calculation scheme: the expected number of accidents, the probability of a spill when an accident occurs, the number of accidents per mile, miles per shipment, and number of shipments. This iteration is repeated for each transportation mode, and followed by calculation of the amount of chemical released to the environment. At this point, the user may begin applying the results to an assessment of exposure in the ambient environment.

This volume does not touch on the number of people potentially exposed as a result of transportation related spills. The report on population enumeration (Volume 4) devotes an entire section to exposed populations along transportation corridors.

5. TYPES OF EXPOSURE ASSESSMENTS

An exposure assessment may be defined either by its level of detail, its accuracy, or its completeness in assessing various exposure scenarios. This document earlier described the planning steps during which the scope and purpose of the assessment are determined; that in large part dictates the type of exposure assessment to be performed. This chapter provides a discussion of five general types of assessments to illustrate how differences in scope and purpose can affect the effort and direction of the assessment. Several of the types of exposure assessments done in OTS are noted as examples.

5.1 Screening Level Assessments

Almost all screening level exposure assessments are performed to determine if there is sufficient exposure potential to warrant further investigation. They usually employ "conservative" assumptions (i.e., "worst-case" or "worst reasonable case"), with the intention of screening out from further concern those situations where worst case estimates would appear to cause little or no concern. Screening level assessments usually roughly estimate exposure to a chemical about which little is known, or prioritize numerous chemicals in terms of predicted exposure. Estimates are often used in lieu of chemical-specific or site-specific data.

Screening level exposure assessments are usually inexpensive and fast, but not necessarily precise. Limited time, dollar, and manpower resources (e.g., assessments must be done on many chemicals, or in a very short time) usually dictate the use of screening level assessments. Because of resource constraints, only relatively easy to find data are usually available to do the assessments. The following types of data may constitute the universe of knowledge about a new or little-known existing chemical to be assessed on a screening level:

- production volume (total annual)
- locations where the chemical is produced
- a brief list of the chemical's uses
- the chemical's formula, structure, and selected physical-chemical properties.

To supplement these basic data, an assessor may also employ estimation techniques that relate chemical properties to one another in order to obtain the parameters essential to determining the chemical's behavior. The solubility, vapor pressure, octanol-water partition coefficient, and similar chemical characteristics can be calculated from a minimum of input data; computerization of the system enables rapid estimation.

These chemical property estimates can then be used, along with other estimation techniques, to determine the magnitude of releases to the environment resulting from production and use. A typical approach might be to apply emission factors (for example, 0.4 percent of production volume is released via wastewater) to estimate releases. The volume of wastewater flow, if unknown, might be assumed to be equal to the average flow rate for the industry.

A screening level fate analysis combines the estimated chemical properties and knowledge about the fate of structurally-similar chemicals to qualitatively address environmental fate. The resulting assessment might make such statements as "the high octanol-water partitioning coefficient indicates that the chemical would adsorb to sediments in an aquatic environment." In keeping with the conservative nature of this type of assessment, however, the approach to calculating aquatic concentrations relies often on assuming dilution, but no removal processes. If the actual location of waterborne discharges is not known, the mean or low-flow rate of streams and rivers receiving this industry sector's wastewater may be assumed.

Human exposure to chemicals in screening assessments is evaluated through the use of scenarios. A scenario combines chemical and product characteristics with use patterns (frequency and duration of use) and intake parameters (breathing rates, etc.) to estimate typical or worst-case exposure. An examination of the chemical's uses may lead to a list of consumer products that could contain the substance. For instance, if the chemical is a fragrance, scenarios of consumer use of cosmetics, soaps, shampoos, and similar products may be constructed.

A screening assessment that indicates potentially significant exposure can lead to more in-depth assessment. Two examples are OTS' Chemical Hazard Information Profile screening assessment of existing chemicals, and the EXposure Assessment Meeting (EXAM) report, the OTS screen for new (premanufacture notice) chemicals.

5.2 Intermediate Level Exposure Assessments

Intermediate level exposure assessments combine the predictive tools described previously with more sophisticated analytic procedures, and involve considerably more detail than a screening level assessment. If worst-case assumptions in a screening level assessment indicate that significant exposure may occur, it is usually in the intermediate level assessment that the assumptions are refined to bring them closer to real-world conditions. Intermediate level assessments are usually considerably more costly than screening level assessments. Where a screening level assessment might be accomplished in hours or days, an intermediate level assessment usually takes weeks or months.

In a typical intermediate level assessment, the source evaluation often includes a materials balance with all points of potential release to the environment quantified; emission factors are supplemented by monitoring data obtained through a literature search. All sources, including inadvertent production, and all identifiable uses are addressed. The fate analysis may combine estimates and analogies with

information derived from the published literature. Where possible, the fate analysis is quantitative, providing rate constants for environmental processes to more precisely define the environmental fate of the substance in all relevant media. All available monitoring data are collected and evaluated for quality and completeness. The results of that review of the monitoring data often dictate whether modeling is performed, and if so, what modeling techniques are necessary. The population analysis is geared toward identifying all potentially exposed individuals and determining the size of specific subpopulations. In support of accurate exposure estimates, the integrated assessment section presents the basis of the exposure estimates: frequency and duration of exposure and physiologic parameters like intake rates. Exposure estimates may be characterized as "typical," "worst-case," or other scenarios.

An important component of this type of exposure assessment is a discussion of the uncertainty of the exposure analysis and a listing of significant data gaps. This section is used to guide planning and to determine the necessity for further action. The chemical may be determined to be of no concern; the data gaps may be substantial enough to warrant field studies; or the data may show enough exposure so that concern for significant potential hazard is raised. OTS performs a number of intermediate level assessments each year, known as Preliminary Existing Chemical Exposure Assessments. Either the need for field studies to gather additional data or the initiation of a regulatory review can prompt OTS to begin a detailed exposure assessment.

5.3 Detailed Exposure Assessments

Detailed exposure assessments often require a significant effort to generate new exposure data, usually to improve the accuracy of the assessment. Field studies and surveys are often the tools used to

generate these new data, so the assessment can be quite expensive. Normally, the field studies will be focused on certain narrow areas of interest, such as a specific occupational setting, consumer use of a specific product, or monitoring exposures at a certain site. The scope, depth, and approach of a detailed assessment make it a very specific document, with a level of accuracy that may be necessary for regulations.

The sources, fate, monitoring, and population studies sections in a detailed exposure assessment would be at least as comprehensive as in an intermediate level assessment. Field studies, surveys, or other data collection activities would be developed for the purpose of filling data gaps and reducing uncertainty. Models used might be verified, and there may be investigation of the accuracy and appropriateness of the scenarios used. Extensive QA/QC measures and analysis of uncertainty is usually done. Because of the complexity usually accompanying field studies, a detailed exposure assessment may often take months to years to complete.

5.4 Special Exposure Assessments

5.4.1 Assessments Limited to Specific Settings

Exposure assessments are often limited to specific settings either by choice of the assessor or by the legislative mandate of the regulatory agency involved; for example, CPSC is concerned only with consumer exposure, and OSHA with occupational exposure. Sometimes settings are limited by the nature of the chemical or its use, as in the case of a captive intermediate (i.e., a consumptive use), where occupational exposure is the only category likely to be significant.

Restricting the assessment to certain settings may automatically narrow the scope in other ways as well by eliminating irrelevant populations, media, and routes from consideration. Nevertheless, all five major components are still typically addressed and limiting the scope to one setting does not preclude the possibility that more than one volume of this series of methods reports may need to be consulted.

5.4.2 Generic Assessments

A generic assessment is one where the non-chemical-specific factors are gathered for the exposure scenarios, but the chemical-specific data are left for future chemical-specific work. The specific chemical data can later be "plugged into" the generic framework, if needed.

In addition to providing a framework for future chemical-specific assessments, generic assessments are also useful for estimating exposure to an entire category of chemicals for screening purposes. The main feature of this type of assessment, as far as planning is concerned, is the emphasis on semi-quantitative predictive methods for estimating environmental concentrations. Results are usually based on the average physicochemical properties of the chemical group and generic release rates.

Analysis of exposed populations can proceed as for other assessments. Scenarios are constructed according to the exposure categories, taking into account frequency and duration of exposure.

Generic assessments are particularly useful for evaluating PMN chemicals, the bulk of which tend to fall into a limited number of well-defined categories (e.g., lubricant additives, AZO dyes). The information contained in the volumes of this series is particularly useful in doing generic exposure assessments.

6. GLOSSARY

Active exposure: Exposure of the user of a consumer product resulting from initial use or application of the product. (cf. "Passive Exposure.")

Aeration: In water treatment, the process by which a gaseous phase, usually air, and water are brought into intimate contact for the purpose of transferring volatile substances to or from the water.

AEROS: Aerometric Emission Reporting System; a data base containing information on point-source atmospheric discharges.

AGRICOLA: The cataloging and indexing base of the National Agricultural Library.

Area source: An emission source defined only by broad geographic boundaries (e.g. urban areas as a source of automotive exhaust).

AT123D: A model for estimating transport in saturated and unsaturated soil zones. See Volume 5.

ATM: Atmospheric Transport Model, used to model point-source atmospheric emissions; see Volume 2. The model may be interfaced with Census Bureau data to allow direct computation of the number of people exposed to various concentrations of a pollutant; see Volume 4.

Atmospheric Box Model: A model used for modeling atmospheric area-source emissions; see Volume 2.

Av, Availability: In dermal exposure calculation, the total amount of skin surface area available for contact with a pollutant during a given activity.

Best Available Technology Review Studies: An industry-specific data base containing information on point-source aquatic discharges.

Block: A Census block is a well-defined piece of land, bounded by streets, roads, railroad tracks, streams, or other features on the ground. Blocks do not cross census tract boundaries, but may cross other boundaries such as city limits. Blocks are the smallest areas for which census data are tabulated.

Block Group (BG): A combination of contiguous blocks having an average population of about 1,100. BGs are subdivisions of census tracts.

Breathing losses: Emissions vented from fixed-roof and floating-roof tanks used for storing volatile liquids.

6. GLOSSARY (continued)

Census County Division (CCD): A modification of the Census-defined category "Minor Civil Division". In 21 states, MCDs were found to be unsuitable for presenting statistics due to area's small population size, frequent boundary changes, etc. CCDs are defined with boundaries that seldom change and can be easily located (e.g., roads, railroads, power lines, and bridges).

Census-Designated Place: A densely settled population center without legally defined limits or corporate powers.

Census Tracts: Small, relatively permanent areas into which metropolitan and certain other areas are divided. An average tract contains about 4,000 residents. All SMSAs are completely tracted.

Central city (of an SMSA): The largest city of an SMSA. One or two additional cities may be added to the SMSA title and identified as central cities providing they meet certain criteria.

CFEST: The Coupled Fluid Energy and Solute Transport model for estimating contaminant concentrations in groundwater; see Volume 5.

Clarification: In water treatment, the process of allowing solids to settle out of the water in a basin.

Coagulation: In water treatment, a process to reduce the net repulsive forces between electrolytes in solution in order to aggregate contaminants associated with turbidity; these are subsequently removed by settling.

Compliance Data System: A data base containing information on point-source atmospheric emissions; see Volume 2.

Consumptive use: In manufacturing, consumptive use occurs when a chemical undergoes a reaction to form a new chemical.

Data Collection Portfolios: A data base containing industry-specific aquatic point-source discharge data.

DIALOG: A computerized data search system.

Direct discharge: The direct release of wastewaters to surface waters without treatment at a POTW.

Disposal: The discharge, deposit, dumping, or placing of any waste into or on land or water.

6. GLOSSARY (continued)

Division: A group of states; a subdivision of a Census region. There are nine divisions: New England, Middle Atlantic, South Atlantic, East South Central, West South Central, East North Central, West North Central, Mountain, and Pacific.

Dust: Airborne solid particles, generated by physical processes such as handling, crushing, or grinding of solids, ranging in size from 0.1 to 25 μ.

EADS: Environmental Assessment Data Systems, a data base containing information on point-source atmospheric and aquatic discharges.

Economic Information System: A computerized data base listing information on facility location and number of employees for companies in the U.S.

Electrostatic precipitator: An air pollution control device.

ENPART: A model for evaluating environmental partitioning; see Volume 2.

Enumeration Districts (EDs): Areas within census tracts, MCDs, and CCDs with an average of about 800 people or 250 housing units. EDs are generally used when block groups are not defined for an area.

EXAMS: Exposure Assessment Modeling System, which considers the fate and transport of a chemical as it passes through a series of water compartments and associated sediment and biotic compartments; see Volume 2 and Volume 5.

Fate: The combined transport and transformation of a pollutant.

FEMWASTE: A mass transport model for soil; combined with FEMWATER, it can predict groundwater flow. See Volume 5.

Flocculation: In drinking water treatment, a process whereby slow mixing of the water and chemicals causes formation of large particles ("floc") by both physical and chemical means.

Fly ash: Combustion residue entrained in the exhaust gases leaving an incinerator.

6. GLOSSARY (continued)

FRDS: Federal Reporting Data System; a data base by the EPA Office of Drinking Water containing inventory data on each public water supply in the U.S.

Fugitive releases: Emissions that occur during manufacturing from leaks in the process equipment and from defective, inadequate, or worn seals in pumps, valves, and compressors; they occur as a result of normal plant operations due to thermal and mechanical stress.

Fume: Solid particles generated by condensation from the gaseous state, generally after volatilization from the molten state. Their formation is often accompanied by oxidation or other chemical reaction. Particles range in size from 0.1 to 5μ.

FURS: The Federal Underground Injection Reporting System, a data base to contain detailed site-specific information on each injection well in the U.S.

GAGE: The Stream Gaging Inventory File, a data base containing the locations of all stream gaging (sampling) stations in the U.S., together with stream flows at those locations and other related information.

Gas: Formless fluids occupying space that can be changed to the liquid or solid state by increased pressure and decreased temperature.

GEMS: Graphical Exposure Modeling System, an interactive computer program managed by OTS, containing models and data bases for assessing exposure; these include ATM-SECPOP, ENPART, EXAMS, etc.

GEOECOLOGY: A computerized data base for environmental data.

GIOAP: The GEOMET Indoor/Outdoor Air Pollution Model for estimating indoor concentrations of toxic chemicals emitted by an outdoor source; see Volume 2.

Hardness: The presence in drinking water of divalent cations, principally calcium and magnesium. If present in excess, hardness is removed by specific treatment processes.

HATREMS: Hazardous and Trace Emissions System, a data base containing information on atmospheric area sources.

6. GLOSSARY (continued)

Hazardous waste: Hazardous waste, as defined in Title 40 of the Code of Federal Regulations, is a legal rather than a scientific term. To be considered hazardous, a waste must be in the list of specific hazardous wastestreams or chemicals, or else it must exhibit one or more of certain specific characteristics including ignitability, corrosivity, reactivity, and toxicity. The definition excludes household waste, agricultural waste returned to the soil, and mining overburden returned to the mine site. It also excludes all wastewater discharged directly or indirectly to surface waters. However, hazardous waste may be physically in the liquid state.

HAZMAT: A data base of the U.S. Department of Transportation, containing information on hazardous materials spills in interstate commerce.

HLDF: The Hydrologically Linked Data File System, a comprehensive group of aquatic data bases useful in the evaluation of drinking water quality, and including the REACH, IFD, WSDB, GAGE, and STORET files, as well as the Pollution-Caused Fishkill File.

HWDMS: Hazardous Waste Data Management System; a computerized system for tracking permit applications for the treatment/storage/disposal of hazardous waste.

HYDRO: An interactive program for accessing data in the HLDF (q.v.).

Incineration: A waste treatment method that involves the controlled burning of wastes resulting in their thermal destruction.

Indirect discharge: The release of wastewater to a POTW for treatment prior to ultimate release to surface waters.

Industrial Facilities Discharge File: A data base containing information on direct and indirect aquatic dischargers within each major industrial category.

Industrial incinerator: Any combustion unit used in the process of burning a nongaseous industrial wastestream which does not recover heat for any useful purpose. (An industrial wastestream is here defined as one composed of more than 50% by weight of waste generated at a manufacturing establishment or collected by a resource recovery establishment).

Industrial solid waste: Any waste generated by a manufacturing process and not disposed of with wastewater; this includes some waste that is physically in the liquid state.

6. GLOSSARY (continued)

Injection well: A waste disposal facility where liquid wastes are injected into a permeable rock layer below the surface.

I-O Matrix: The Industry-Occupation Matrix, a compilation of employment data.

IWIS: The Injection Well Inventory System, a data base containing inventory information on injection wells.

Lagoon: A surface impoundment.

Land treatment: A disposal technique by which wastes are mixed with surface soil and allowed to be degraded through natural processes.

Landfill: A waste disposal site where wastes are placed on the ground and covered with soil; see "Sanitary Landfill" and "Open Dump".

Landspreading: Same as land treatment.

Leachate: Liquid released into soil from a land disposal facility. Leachate is generated when water enters a landfill, migrates through it picking up soluble materials, and seeps into the soil.

Line source: An emission source that is mobile, following a pathway such as a road, railway, or river.

LOMA: The Leachate Organic Migration and Alternation Model for predicting the transport of organic solutes in soil; see Volume 5.

Maximum Contaminant Levels: A set of standards for public drinking water set by the Safe Water Drinking Act.

Medium: The environmental vehicle by which a pollutant is carried to the receptor (e.g., air, surface water).

Metric ton: Same as kkg.

Microenvironment: A region of local variability within an environment. The microevironments discussed in Volume 2 include the indoor, outdoor, and in-vehicle microenvironments.

Minor Civil Divisions (MCDs): These are the primary poltical and administrative subdivisions of counties, most frequently known as townships, but in some states including towns, precincts, and magisterial districts.

6. GLOSSARY (continued)

Mist: Suspended liquid droplets generated by condensation from the gaseous to the liquid state or by dispersion of a liquid, ranging in size from 0.5 to 1,000μ.

MMT: The Multicomponent Mass Transport model for predicting movement of radioactive contaminants in the soil; see Volume 5.

Municipal incinerator: Any incinerator that burns at least 50% municipal solid waste.

Municipal landfill: Any landfill, publicly or privately owned and operated, that accepts municipal waste; as defined in Volume 3, "municipal landfills" include off-site industrial landfills.

National Occupational Hazard Survey: A 2-year field study initiated by NIOSH in 1972 to describe the health and safety conditions in the American work environment.

National Pollutant Discharge Elimination System: This is a permit issuing program designed to monitor and control the discharge of pollutants into the nation's surface waters. The NPDES compliance files contain aquatic point-source discharge monitoring data.

NAWDEX: National Water Data Exchange; an interagency data base managed by USGS to assist in identifying, locating, and acquiring water data.

NEDS: National Emissions Data System, a data base containing information on atmospheric area source emissions.

NEEDS: A computerized data base containing information collected in annual surveys conducted by the EPA Office of Water Programs Operations. It includes design and operating characteristics for all municipal sewage treatment facilities in the U.S.

Open dump: Any landfill not meeting the criteria for a sanitary landfill (q.v.).

ORBIT: A computerized data search system.

Partitioning: The relative distribution of a substance among environmental compartments (e.g. air, surface water, sediment, biota, soil).

Passive exposure: Exposure arising subsequent to the initial use or application of a consumer product, usually affecting persons in addition to the initial user. (cf. "Active Exposure.")

6. GLOSSARY (continued)

PATHS: A model for estimating contaminant flow in soil; see Volume 5.

Pathway: A history of the flow of a pollutant from source to receptor, including qualitative descriptions of emission type, transport, medium, and exposure route.

Periodicity: In exposure calculation, the product of frequency and duration of exposure; in emission characterization, a monitored or estimated schedule of emissions from the source.

PEST: A dynamic simulation model that evaluates the fate of toxic organic compounds in freshwater environments; see Volume 5.

PESTAN: A screening model that evaluates a chemical's potential for groundwater contamination; see Volume 5.

PIRS: The Pollution Incident Reporting System for collecting Coast Guard reports on hazardous materials spills from barges.

PLUME: A steady-state analytical model for estimating contaminant transport in the saturated zone of soil; see Volume 5.

PMS: The Pollutant Movement Simulator, a model that describes air-water flow in a coupled unsaturated-saturated porous medium; see Volume 5.

Point source: A known location of emissions identifiable by geographic coordinates (e.g., industrial dischargers, disposal sites.)

Preliminary treatment: Wastewater treatment involving only communition, screening, and/or grit removal.

Premanufacturing notice (PMN): A notification of intent to produce or import a new chemical substance. It is submitted to EPA by the manufacturer or importer, and is required to contain information on proposed production amounts, uses, occupational exposure levels, disposal methods, etc.

Primary producer: The industry that extracts or starts the manufacturing process with raw material and modifies it to produce an intermediate or a finished product.

Primary treatment: Wastewater treatment producing effluent that does not meet regulatory standards for secondary treatment. Conventional primary treatment provides preliminary treatment plus primary sedimentation to remove settlable solids; advanced primary treatment includes some biological treatment as well.

6. GLOSSARY (continued)

Process releases: Emissions that occur during a manufacturing process, and are inherent in the unit operations that make up the process.

Publicly-owned treatment works: Municipal sewage treatment plant.

REACH File: A series of 11-digit numerical codes that uniquely identify every major stream, river, or lake segment in the U.S. Each REACH number combines the 8-digit USGS hydrologic unit with a 3-digit EPA segment number.

Reduction: Any waste treatment method that decreases waste volume, such as wet oxidation or incineration.

Region: A large, geographically contiguous group of states (with the exception of the region that includes Alaska and Hawaii). There are four Census regions (Northeast, North Central, South, and West) and 10 EPA Regions.

Route: The means by which a pollutant in a given medium contacts or enters the receptor (e.g., inhalation, ingestion).

Rural Area: By Census definition, any area not classified as urban (q.v.).

Sanitary landfill: Any landfill meeting the criteria set forth in Sec. 4004 of RCRA, as opposed to "open dump". Sanitary landfills must meet stringent siting and operational standards.

SAROAD: Storage and Retrieval of Aerometric Data, a data base for atmospheric ambient monitoring information.

Scenario: A set of assumptions about how exposure takes place. Scenarios are usually constructed in the "Integrated Exposure Analysis" section of an exposure assessment, and are usually specific to an exposure setting.

Secondary producer: The industry that processes and uses an intermediate to form other products.

Secondary releases: Emissions which result from the handling, treatment, and disposal of aqueous, liquid, and solid wastes generated by an industry.

Secondary treatment: Wastewater treatment comprising preliminary plus biological processes (i.e. trickling filter, activated sludge, rotating biological contactors) with no additional process except disinfection. Advanced secondary treatment consistently provides effluents with low BOD and the removal of nutrients, phosphorus, and ammonia.

SECPOP: A computerized population distribution model; see "ATM" and Volume 4.

SESOIL: The Seasonal Soil Compartment Model, a mathematical model for long-term environmental pollutant fate simulations that describes water transport, pollutant transport/transformation, and soil quality. It may be used to predict leachate contamination of groundwater as well as gas emissions to the atmosphere.

Setting: One of seven OTS-defined exposure categories; see Volume 1, Table 3.

Severity: In inhalation exposure calculation, the product of ambient concentration and ventilation rate; in dermal exposure calculation, the product of concentration and availability.

Sewage sludge incinerator: An incinerator that burns more than 50% sewage sludge.

SITEHELP: An interactive program for accessing data in the HLDF (q.v.).

SRI data base: A computerized data base that offers statistical analysis and retrieval of human time-diary data.

Stabilization: Treatment of sludge by digestion of organic solids.

Standard Consolidated Statistical Area (SCSA): A census region composed of two or more contiguous SMSAs which meet certain criteria of population size, urban character, social and economic integration, and contiguity of urbanized areas.

Standard Industrial Classification (SIC): A comprehensive series of 2- to 4- digit codes used by the U.S. Department of Commerce to designate segments of industry, commerce, and agriculture.

Standard Metropolitan Statistical Area (SMSA): As defined by the Census Bureau, an integrated economic and political unit with at least one densely populated central city. Generally, each SMSA consists of one or more entire counties, or county equivalents, that meet standards pertaining to population and metropolitan character.

6. GLOSSARY (continued)

STAR: The Stability Array Program, which provides data on atmospheric stability, wind direction, and wind speed, based on National Weather Service data, for input to air models; see Volume 2.

STDM: The Solute Transport and Dispersion Model for predicting the movement of contaminants in soil; see Volume 5.

STF: Summary Tape Files, a computerized source of Census information.

STORET: Storage and Retrieval of Water Quality and Related Data, a data base containing information on ambient water quality monitoring.

Surface Impoundment: A waste handling facility where liquid wastes are treated, stored, or disposed of in a natural or manmade topographical depression.

Surface Impoundment Assessment: An inventory of surface impoundments in the U.S., together with data on their potential effects on groundwater quality.

SWIFP: A model for predicting the movement of contaminants in soil, see Volume 5.

SWIP: The Survey Waste Injection Program, a model for investigating contaminant movement associated with injection wells.

Tertiary treatment: Wastewater treatment producing effluent with a BOD less than 10 mg/l and capable of removing more than 50% total nitrogen from the influent wastewater.

Transformation: The chemical alteration of a pollutant in the environment via biodegradation, photolysis, hydrolysis, or other means. (see "Transportation.")

Transport: The mass movement of a pollutant via hydrological, meteorological, or other physical processes, including intermedia transfer. (see "Transformation.")

Treatment: Any process designed to change the physical, chemical, or biological character or composition of a waste for the purpose of making it safer for transport, amenable for recovery or storage, or reduced in volume.

UIC: The Underground Injection Control program, by which states are required to develop programs to prevent groundwater contamination brought about by deep well injection of wastes.

6. GLOSSARY (continued)

UNAMAP: User's Network for Applied Modeling of Air Pollution, a series of atmospheric line-source models; see Volume 2.

UNSATID: The One-Dimension Saturated Flow model for predicting flow in the saturated zone of soil; see Volume 5.

Urban area: By Census definition, an urbanized area or a place of 2,500 habitants or more outside urbanized areas.

Urbanized area: By Census definition, an area containing a central city (or twin cities) meeting the same criteria as an SMSA, plus the surrounding closely settled incorporated and unincorporated areas which meet certain criteria of population size of density.

Vapor: Gaseous form of a substance normally in the liquid or solid state at normal temperature and pressure.

WAS: Waste Age Survey, an inventory of landfills conducted on roughly an annual basis by Waste Age magazine.

WATSTORE: Water Data Storage and Retrieval System; a data bank for all information collected by USGS at its water sampling sites throughout the U.S.

WHIM: Wisconsin Hydrologic Transport Model, which simulates the movement of a chemical through an inland watershed; see Volume 5.

WSDB: The Water Supply Data Base, which contains information on the locations of surface-water-derived drinking water utilities, including locations of treatment plants, intakes, and sources, populations served, and average and maximum daily production.

7. ABBREVIATIONS

BAT: Best Available Technology

BG: Block Group.

BMCS: The Bureau of Motor Carrier Safety of the U.S. Department of Transportation.

BOD: Biological oxygen demand.

CAS: Chemical Abstracts Service.

CCD: Census County Division

CDP: Census-Designated Place.

CDS: Compliance Data System.

CPSC: Consumer Products Safety Commission.

DOT: U.S. Department of Transportation.

ED: Enumeration District.

EGD: (USEPA) Effluent Guidelines Division.

EIS: Economic Information System.

ESP: Electrostatic precipitator.

FWPCA: Federal Water Pollution Control Act (P.L. 95-217).

GPO: U.S. Government Printing Office.

HLDF: Hydrologically Linked Data File

HO: Halogenated organic.

IFD: Industrial Factilities Discharge.

MCD: Minor Civil Division.

MCL: Maximum Contamination Level.

MDSD: (USEPA) Monitoring and Data Support Division.

mgd: Millions of gallons per day.

7. ABBREVIATIONS (continued)

MSW: Municipal solid waste.

MTB: The Materials Transportation Bureau of the U.S. Department of Transportation.

NEMCOG: Mortheast Michigan Council of Governments.

NIOSH: National Institute for Occupational Safety and Health.

NOAA: U.S. National Oceanic and Atmospheric Administration.

NOHS: National Occupational Hazard Survey.

NPDES: National Pollutant Discharge Elimination System.

NPTOC: Nonpurgeable total organic carbon.

NTA: Nitrilotriacetic acid.

NTIS: National Technical Information Service.

OSHA: U.S. Occupational Safety and Health Administration.

OSW: (USEPA) Office of Solid Waste.

OTS: (USEPA) Office of Toxic Substances.

PMN: Premanufacturing notice.

POTW: Publicly-owned treatment works.

RCRA: Resource Conservation and Recovery Act of 1976 (P.L. 94-580).

RDF: Refuse-derived fuel.

SCSA: Standard Consolidated Statistical Area.

SDF: Stream dilution factor.

SIA: Surface Impoundment Assessment.

SIC: Standard Industrial Classification.

SL: Sanitary landfill.

7. ABBREVIATIONS (continued)

SMRB: Simmons Market Research Bureau.

SMSA: Standard Metropolitan Statistical Area.

SOCMI: Synthetic organic chemicals manufacturing industry (SIC 28).

THM: Trihalomethane.

TOCl: Total organic chlorine.

TPY: tons per year.

TSCA: The Toxic Substances Control Act of 1976 (P.L. 94-469).

TSD: Treatment/storage/disposal.

USDI: U.S. Department of the Interior.

USDW: Underground source of drinking water.

USGS: U.S. Geological Survey.

USACE: U.S. Army Corps of Engineers.

VOC: Volatile organic carbon.

WAS: Waste Age Survey.

WMT: Wet metric tons.

8. REFERENCES

Callahan MA. 1982. Planning an exposure assessment. Draft. Washington, DC: Office of Toxic Substances, U.S. Environmental Protection Agency.

USEPA. 1984. Proposed guidelines for exposure assessment; request for comments. Federal Register 49:227 (23 November 1984), p. 46304.

Preceding page blank

Appendix

Table of Contents from Each Volume in the Exposure Assessment Methods Series

Preceding page blank

VOLUME 2 - METHODS FOR ASSESSING EXPOSURE TO CHEMICAL SUBSTANCES IN THE AMBIENT ENVIRONMENT

Preceding page blank

TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	1
	1.1 Purpose and Scope	1
	1.2 Report Organization	2
	1.3 Framework for Calculation	2
	1.3.1 Inhalation Exposure of Humans	4
	1.3.2 Dermal Exposures of Humans	4
	1.3.3 Exposure of Aquatic Biota	7
2.	SOURCES	8
3.	ENVIRONMENTAL PATHWAYS	13
	3.1 Physicochemical Properties	13
	3.1.1 General Properties	13
	3.1.2 Particle Size Analysis for Airborne Pollutants	17
	3.2 Partitioning	17
	3.2.1 Analogy with Other Compounds	17
	3.2.2 Mathematical Models	20
	3.2.3 Empirical Methods	24
	3.3 Environmental Pathway Models	25
4.	MONITORING DATA	27
	4.1 Sources	27
	4.1.1 Air Emissions	27
	4.1.2 Water Discharges	31
	4.2 Ambient	32
	4.2.1 Air	33
	4.2.2 Water	33
	4.3 Background	34
	4.3.1 Air	34
	4.3.2 Water	36

Preceding page blank

TABLE OF CONTENTS (continued)

	Page No.
4.4 Personal Monitoring	36
4.5 Analytical Techniques	40
4.5.1 Organics	41
4.5.2 Inorganics	41
5. EXPOSED POPULATIONS	46
6. CALCULATING EXPOSURES	48
6.1 Identification of Exposed Populations	48
6.1.1 Ambient Air	48
6.1.2 Ambient Water	49
6.1.3 Aquatic Biota	50
6.2 Inhalation Exposures	50
6.2.1 Periodicity	55
6.2.2 Ventilation Rate	56
6.2.3 Ambient Air Concentrations	64
6.3 Dermal Exposure	86
6.3.1 Frequency and Duration	86
6.3.2 Availability	87
6.3.3 Ambient Aqueous Concentration	87
6.4 Exposure of Aquatic Biota	104
7. REFERENCES	105

VOLUME 3 - METHODS FOR ASSESSING EXPOSURE FROM DISPOSAL OF CHEMICAL SUBSTANCES

TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	1
1.1	Purpose and Scope	1
1.2	Limitations	2
1.3	Overview - Potential for Exposure to Chemical Substances from Waste Disposal	3
2.	GENERAL METHODOLOGICAL APPROACH	6
2.1	Integration with Other Exposure Scenarios	7
2.2	Framework for Estimating Releases	7
2.3	General Decision Trees for Stages I through V	10
2.3.1	Stage I Decision Tree - Estimating Releases to Disposal	11
2.3.2	Stage II Decision Tree - Characterizing Waste Stream Releases and Concentrations	13
2.3.3	Stage III Decision Tree - Allocating Waste Streams to Disposal Practices	14
	(1) Incinerator residues	19
	(a) Background information	19
	(b) Stage III decision tree	23
	(2) POTW sludge	25
	(a) Background information	25
	(b) Stage III decision tree	27
	(3) Wastewater	29
	(a) Background information	30
	(b) Stage III decision tree	31
	(4) Hazardous Waste	35
	(a) Background information	35
	(b) Stage III decision tree	38
	(5) Nonhazardous industrial solid waste	41
	(a) Background information	41
	(b) Stage III decision tree	45
	(6) Municipal Solid Waste (MSW)	46
	(a) Background information	46
	(b) Stage III decision tree	49
2.3.4	Stage IV Decision Tree - Allocating Waste Streams Streams to Individual Disposal Sites	50
2.3.5	Stage V Decision Tree - Estimating Environmental Releases from Disposal Sites	53

Preceding page blank

TABLE OF CONTENTS (continued)

		Page No.
3.	LANDFILLS	56
	3.1 Background Information	56
	3.1.1 Landfill Types and Operation	56
	3.1.2 Environmental Releases from Landfills	57
	3.1.3 Predicting Environmental Releases	60
	3.1.4 Model Input Data	62
	3.1.5 Additional Considerations for Modeling Chemical Releases from Landfills	74
	3.1.6 Estimating Emissions from Broad Geographical Regions	82
	3.1.7 Monitoring	82
	3.2 Allocating Waste Streams to Landfill Sites - Stage IV Decision Tree	83
	3.2.1 Municipal Landfills	83
	3.2.2 Industrial Nonhazardous Landfills	84
	3.2.3 Hazardous Waste Landfills	85
	3.3 Estimating Environmental Releases from Landfills - Stage V Decision Tree	86
	3.3.1 Municipal Landfills	87
	3.3.2 Industrial Landfills	89
4.	LAND TREATMENT	91
	4.1 Background Information	91
	4.1.1 Types of Waste Treated	92
	4.1.2 Environmental Impacts and Environmental Releases	95
	4.1.3 Location of Sites	97
	4.1.4 Estimating Environmental Releases	98
	4.1.5 Model Input Data	100
	4.1.6 Monitoring	104
	4.2 Allocating Waste Streams to Land Treatment Sites - Stage IV Decision Tree	104
	4.3 Estimating Environmental Releases from Land Treatment - Stage V Decision Tree	106

TABLE OF CONTENTS (continued)

	Page No.
5. SURFACE IMPOUNDMENTS	110
5.1 Background Information	110
5.1.1 Types of Impoundments	111
5.1.2 Environmental Releases from Surface Impoundments	115
5.2 Allocating Waste Streams to Surface Impoundments - Stage IV Decision Tree	118
5.3 Estimating Environmental Releases from Surface Impoundments - Stage V Decision Tree	127
6. PUBLICLY OWNED TREATMENT WORKS (POTWs)	134
6.1 Background Information	134
6.1.1 General	134
6.1.2 Chemical Substances in POTW Effluent and Sludge	136
6.1.3 Predicting Releases of Chemical Substances from POTWs	136
6.2 Allocating Wastewater to Individual POTWs - Stage IV Decision Tree	140
6.3 Estimating Releases from POTWs - Stage V Decision Tree	142
7. INCINERATION	145
7.1 Background Information	145
7.1.1 General	145
7.1.2 Information Resources	147
7.1.3 Emissions and Products of Incineration	149
7.1.4 Estimating Emissions from Incineration	153
7.2 Allocating Waste Streams to Individual Incinerators - Stage IV Decision Tree	154
7.3 Estimating Emissions from Incineration - Stage V Decision Tree	157

TABLE OF CONTENTS (continued)

	Page No.
8. DEEP-WELL INJECTION	161
8.1 Background Information	161
8.1.1 General	161
8.1.2 Information Resources Useful in Assessing the Potential for Exposure from Injection Wells	166
8.1.3 Modeling Releases to Groundwater	166
8.2 Allocating Waste Streams to Individual Injection Wells-Stage IV Decision Tree	167
8.3 Estimating Releases from Injection Wells - Stage V Decision Tree	169
REFERENCES	172

VOLUME 4 - METHODS FOR ENUMERATING AND CHARACTERIZING POPULATIONS EXPOSED TO CHEMICAL SUBSTANCES

TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	1
	1.1 Purpose and Scope	1
	1.2 Report Organization	1
	1.3 Framework of Methods	2
2.	POPULATIONS EXPOSED TO CHEMICAL SUBSTANCES IN THE AMBIENT ENVIRONMENT	5
	2.1 Introduction	5
	2.2 Identification of Exposed Populations	5
	2.3 Methods for the Enumeration of Exposed Populations	9
	2.3.1 Census of Population	9
	2.3.2 Enumeration of Populations Exposed via Inhalation	35
	2.3.3 Enumeration of Populations Exposed via Dermal Contact	56
	2.3.4 Enumeration of Non-Human Populations	59
	2.4 Characterization of Exposed Populations	61
	2.4.1 Populations Exposed via Inhalation	61
	2.4.2 Population Exposed via Dermal Contact	63
	2.5 References	66
3.	POPULATIONS EXPOSED TO CHEMICAL SUBSTANCES IN THE OCCUPATIONAL ENVIRONMENT	69
	3.1 Introduction	69
	3.2 Identification of Exposed Populations	69
	3.3 Methods for the Enumeration of Exposed Populations	72
	3.3.1 Enumeration of Populations Identified by SIC Code	73
	3.3.2 Enumeration of Populations Defined by Occupation and Industry	77
	3.3.3 Enumeration of Site-Specific Populations	79
	3.4 Characterization of Occupationally Exposed Populations	82
	3.5 References	87

Preceding page blank

TABLE OF CONTENTS (Continued)

		Page No.
4.	POPULATIONS EXPOSED TO CHEMICAL SUBSTANCES VIA THE INGESTION OF FOOD	89
	4.1 Introduction	89
	4.2 Identification of Exposed Populations	89
	4.3 Methods for the Enumeration of Exposed Populations	91
	4.3.1 Enumeration of Populations Exposed as a Result of Agricultural Practices	93
	4.3.2 Enumeration of the Populations Exposed as a Result of Processing and Packaging	94
	4.3.3 Enumeration of Populations Exposed as a Result of Releases from Other Sources	98
	4.3.4 Enumeration of Exposed Populations by the Use of Monitoring Data	106
	4.4 Characterization of the Exposed Population	111
	4.5 References	115
5.	POPULATIONS EXPOSED TO CHEMICAL SUBSTANCES VIA THE USE OF CONSUMER PRODUCTS	117
	5.1 Introduction	117
	5.2 Identification of Exposed Populations	117
	5.3 Methods for the Enumeration of Exposed Populations	120
	5.3.1 Enumeration of Exposed Populations via Simmons Market Research Bureau Reports	120
	5.3.2 Enumeration of Exposed Populations via Production and Sales Data	138
	5.3.3 Enumeration of Exposed Populations via Chemical-Specific Information	138
	5.3.4 Enumeration of Consumers Performing Amateur or Hobbyist Activities	141
	5.4 Characterization of Exposed Populations	142
	5.5 References	146

TABLE OF CONTENTS (Continued)

	Page No.
6. POPULATIONS EXPOSED TO CHEMICAL SUBSTANCES VIA THE INGESTION OF DRINKING WATER	147
6.1 Introduction	147
6.2 Identification of Exposed Populations	149
6.3 Methods for the Enumeration of Exposed Populations	149
6.3.1 Enumeration of Populations in Specific Geographic Areas	151
6.3.2 Enumeration of Populations Exposed via Treatment Methods	160
6.3.3 Enumeration of Exposed Populations by Type of Distribution System	163
6.3.4 Enumeration by Use of Monitoring Data	165
6.4 Characterization of Exposed Populations	168
6.5 References	169
APPENDIX A: APPLICATION OF METHODS TO EXAMPLE PROBLEMS	171
Introduction	173
A-1. Populations Exposed to Chemical Substances in the Ambient Environment	174
A-2. Populations Exposed to Chemical Substances in the Occupational Environment	200
A-3. Populations Exposed to Chemical Substances via the Ingestion of Food	208
A-4. Populations Exposed to Chemical Substances via the Use of Consumer Products	214
A-5. Populations Exposed to Chemical Substances via the Ingestion of Drinking Water	225
APPENDIX B: EXAMPLES OF DATA BASES USED IN OCCUPATIONAL POPULATIONS METHODS SECTION	233

VOLUME 5 - METHODS FOR ASSESSING EXPOSURES TO CHEMICAL SUBSTANCES IN DRINKING WATER

TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	1-1
	1.1 Purpose and Scope	1-1
	1.2 Methodological Framework	1-2
2.	DRINKING WATER SYSTEMS AND EXPOSURE PATHWAYS	2-1
	2.1 Sources of Contamination	2-1
	2.2 Drinking Water Supplies	2-1
	2.3 Water Treatment Processes	2-6
	2.4 Distribution Systems	2-8
	2.5 Uses of Finished Water	2-9
	2.6 Water Quality Requirements	2-9
3.	IDENTIFICATION OF CONTAMINATED WATER SUPPLIES	3-1
	3.1 Identification of Surface Water Supplies	3-1
	3.1.1 Hydrologically Linked Data File (HLDF) System	3-2
	3.1.2 Federal Reporting Data System (FRDS)	3-22
	3.2 Identification of Ground Water Supplies	3-24
	3.2.1 Identifying Site-Specific Ground Water Supplies	3-25
	3.2.2 Identifying Nonsite-Specific Ground Water Supplies	3-27
4.	QUANTIFICATION OF RAW WATER CONCENTRATIONS OF CHEMICAL SUBSTANCES	4-1
	4.1 Monitoring Data	4-1
	4.2 Estimation of Concentration in Surface Water	4-5
	4.2.1 Conservative Estimate	4-5
	4.2.2 Chemical Fate Models	4-11
	4.3 Estimation of Concentration in Ground Water	4-22
	4.3.1 Release Rate Models	4-23
	4.3.2 Solute Transport Models	4-26
	4.3.3 Practical Model Application	4-33

Preceding page blank

TABLE OF CONTENTS

		Page No.
5.	CONCENTRATION OF CHEMICAL SUBSTANCES IN FINISHED WATER.....	5-1
	5.1 Public Water Systems.....	5-1
	5.1.1 Unit Processes in Water Treatment.....	5-1
	5.1.2 Addition of Contamination during Water Treatment and Distribution.....	5-28
	5.1.3 Calculation of Finished Water Contaminant Concentrations.....	5-33
	5.2 Private Systems.....	5-39
	5.2.1 Guidelines for Selection of Suitable Private Drinking Water Sources.....	5-40
	5.2.2 Home Drinking Water Treatment Systems.....	5-40
6.	EXPOSED POPULATIONS.....	6-1
	6.1 Identification of Exposed Populations.....	6-1
	6.2 Enumeration of Exposed Populations.....	6-2
	6.3 Characterization of Exposed Populations.....	6-5
7.	CALCULATION OF EXPOSURE.....	7-1
8.	REFERENCES.....	8-1

VOLUME 6 - METHODS FOR ASSESSING OCCUPATIONAL EXPOSURE TO CHEMICAL SUBSTANCES

TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	
	1.1 Purpose and Scope	1
	1.2 Methodology Framework	1
	1.3 Organization of the Report	4
2.	Sources	5
	2.1 Determining Chemical Manufacturing, Processing, and Use Locations	8
	2.2 Identifying Production and Use Processes and Activities	8
	2.2.1 Manufacturing	8
	2.2.2 Processing	13
	2.2.3 General Industrial Worker Activities	16
	2.2.4 Activities of Wholesale and Retail Trade	19
3.	MONITORING DATA	20
	3.1 QA/QC Considerations	21
	3.1.1 Sample Design	22
	3.1.2 Sample Collection	22
	3.1.3 Analytical Measurement Systems	22
	3/1/4 Data Entry and Processing	23
	3.2 Types of Monitoring	23
	3.2.1 Personal/Breathing Zone Monitoring	24
	3.2.2 Workplace or Area Monitoring	24
	3.2.3 Biological Monitoring	24
	3.3 Sample Collection Techniques	24
	3.3.1 Types of Samples	25
	3.3.2 Employees Sampled	25
	3.4 Exposure Measurement Strategies	26
	3.4.1 Sample Measurement	27
	3.4.2 Length and Duration of Measurement	27

Preceding page blank

TABLE OF CONTENTS (continued)

	Page No.
3.5 Available Information on Occupational Exposure	29
3.5.1 National Institute of Occupational Safety and Health	31
3.5.2 Occupational Safety and Health Administration.....	35
3.6 Summary	37
4. ESTIMATING CONTAMINANT RELEASES IN THE OCCUPATIONAL SETTING	39
4.1.2 The Mass Balance Approach	40
4.1.3 Estimating Releases	42
5. ENVIRONMENTAL FATE AND EXPOSURE PATHWAYS	60
5.1 Workplace Air Contaminant Fate Processes	60
5.1.1 Indoor Transport Processes	60
5.1.2 Indoor Air Contaminant Removal Mechanisms.....	62
5.1.3 Outdoor Airborne Contaminant Fate Processes...	68
5.2 Estimating Air Concentrations in the Indoor Occupational Setting	70
5.3 Estimating Air Concentrations in the Outdoor Occupational Setting	77
5.3.1 Ground Level Releases	78
5.3.2 Vent Releases	80
6. EXPOSED POPULATIONS ANALYSIS	82
6.1 Identification and Enumeration of Exposed Populations	82
6.1.1 Generic Identification and Enumeration Data ...	83
6.1.2 Specific Identification and Enumeration Data	84
6.2 Population Characterization	85
6.3 Frequency and Duration of Occupational Exposure	85
6.3.1 Frequency and Duration	85
6.3.2 Worklife	89

TABLE OF CONTENTS (continued)

	Page No.
7. CALCULATING EXPOSURE	96
7.1 Introduction	96
7.2 Inhalation Exposure	97
7.3 Dermal Exposure	101
7.3.1 Exposure to a Film of Liquid Deposited on the Skin	101
7.3.2 Immersion in Liquids	102
7.3.3 Exposure to Dusts and Powders	102
7.4 Ingestion Exposure	106

VOLUME 7 - METHODS FOR ASSESSING CONSUMER EXPOSURE TO CHEMICAL SUBSTANCES

Preceding page blank

TABLE OF CONTENTS

Page No.

1. INTRODUCTION..... 1-1

1.1 Background and Purpose..... 1-1
1.2 Federal Regulatory Authority over Consumer Products..... 1-2
1.3 Consumer Products Considered by This Methods Report..... 1-6
1.4 Overview of Methodological Approach..... 1-15

2. PHYSICAL-CHEMICAL PROPERTIES..... 2-1

2.1 General Property Information..... 2-1
2.2 Data Gathering..... 2-1
2.2.1 Sources of Experimental Data..... 2-5
2.2.2 Methods for Estimating Physical-Chemical Properties.. 2-9
2.3 Summary..... 2-9

3. IDENTIFICATION OF CONSUMER PRODUCTS AND FORMULATIONS..... 3-1

4. METHODS FOR ESTIMATING RELEASE OF CHEMICALS FROM CONSUMER PRODUCTS AND EXPOSURE CONCENTRATIONS..... 4-1

4.1 Overview of Exposure Pathways, Chemical Release Processes, and Factors Affecting Exposure Concentrations..... 4-2

4.1.1 Chemical Release Processes..... 4-3
4.1.2 Factors Affecting Exposure Concentrations..... 4-5

4.2 Consumer Environment Monitoring Data..... 4-6
4.3 Methods to Estimate Contaminant Release from Consumer Products..... 4-7

4.3.1 Release of Aerosols from Consumer Products..... 4-7
4.3.2 Chemical Release from Liquid Films..... 4-8
4.3.3 Chemical Release from Liquids and Solids..... 4-12

4.4 Methods for Calculating Exposure Concentrations..... 4-19

4.4.1 Concentrations Resulting from Instantaneous Release of Chemicals..... 4-19
4.4.2 Concentrations Resulting from Continuous Release of Chemicals..... 4-27
4.4.3 Direct Contact with Contaminant Source..... 4-30

4.5 Potential Refinements to Existing Methods..... 4-31

Preceding page blank

TABLE OF CONTENTS (Continued)

Page No.

5. EXPOSED POPULATIONS..... 5-1

5.1 Identification of Exposed Populations..... 5-1
5.2 Enumeration of the Exposed Population..... 5-2

5.2.1 Enumeration of Exposure Populations via Simmons Market Research Bureau Reports..... 5-2
5.2.2 Enumeration of Exposed Populations via Production and Sales Data..... 5-4
5.2.3 Enumeration of Exposed Populations via Chemical-Specific Information..... 5-4

5.3 Characterization of Exposed Populations..... 5-5

6. EXPOSURE ANALYSIS..... 6-1

6.1 Exposure Pathways and Routes..... 6-1

6.1.1 Inhalation Pathways..... 6-2
6.1.2 Dermal Pathways..... 6-3
6.1.3 Ingestion Pathways..... 6-5
6.1.4 Other Pathways..... 6-7

6.2 Exposure Calculation..... 6-8

6.2.1 Frequency and Duration..... 6-8
6.2.2 Inhalation Exposure..... 6-11
6.2.3 Dermal Exposure..... 6-28
6.2.4 Ingestion..... 6-35

6.3 Absorbed Dose..... 6-36

6.3.1 Inhalation..... 6-36
6.3.2 Dermal..... 6-36
6.3.3 Ingestion..... 6-42

6.4 Exposure Scenarios..... 6-47
6.4.1 Inhalation Exposure Scenarios..... 6-48
6.4.2 Dermal Exposure Scenarios..... 6-49
6.4.3 Ingestion Scenarios..... 6-49

7. REFERENCES..... 7-1

TABLE OF CONTENTS (Continued)

Page No.

APPENDIX A. Consumer Exposure Scenarios
APPENDIX B. Exposure Assessment Data Sheets
APPENDIX C. Information Resource Summaries
APPENDIX D. Simmons Market Research Bureau (SMRB) Reports

VOLUME 8 - METHODS FOR ASSESSING ENVIRONMENTAL PATHWAYS OF FOOD CONTAMINATION

Preceding page blank

TABLE OF CONTENTS

	Page No.
1. INTRODUCTION	1-1
1.1 Purpose and Scope	1-1
1.2 Organization of the Report	1-1
2. EXISTING METHODOLOGIES	2-1
2.1 U.S. EPA Office of Radiation Programs	2-1
2.2 U.S. EPA Office of Pesticide Programs	2-2
2.3 FDA	2-3
2.4 Summary	2-4
3.. OVERALL METHODOLOGICAL FRAMEWORK	3-1
3.1 Approach	3-1
3.1.1 General Discussion	3-1
3.1.2 Step by Step Approach	3-9
3.1.2.1 Step 1 Determine the Scope of the Assessment	3-10
3.1.2.2 Step 2 Collect Available Residue for Food	3-13
3.1.2.3 Step 3 Pathways Approach	3-13
3.1.2.4 Step 4 Estimate Concentrations in Food	3-13
3.1.2.5 Step 5 Compile Food Concentration Data	3-14
3.1.2.6 Step 6 Collect Appropriate Consumption Data	3-14
3.1.2.7 Step 7 Estimate Individual Dietary Intake	3-15
3.1.2.8 Step 8 Consider Population Exposed	3-15
3.2 Data Sources	3-16
3.2.1 Concentration Data	3-17
3.2.2 Consumption Data	3-17
3.2.3 Population Data	3-20
4. SUMMARY AND EXAMPLE	4-1
5. REFERENCES	5-1

Preceding page blank

TABLE OF CONTENTS

	Page No.
APPENDIX A - PATHWAYS OF FOOD CONTAMINATION	A-1
APPENDIX B - QUANTITATIVE METHODS	B-1
APPENDIX C - EXAMPLE OF PATHWAYS APPROACH AND QUANTITATIVE METHODS	C-1

VOLUME 9 - METHODS FOR ESTIMATING EXPOSURE TO CHEMICAL SUBSTANCES RESULTING FROM TRANSPORTATION-RELATED SPILLS

TABLE OF CONTENTS

		Page No.
1.	INTRODUCTION	1
2.	GENERAL METHODOLOGY	2
	2.1 Probability of a Spill	3
	2.2 Quantity Spilled	4
	2.3 Extent of Exposure	5
	2.4 Environmental Releases	6
	2.5 Spill Exposure Assessment Methodology	7
	2.6 Conclusions	8
3.	DETERMINATION OF COMMODITY SHIPPING PATTERNS	9
	3.1 Importation of Commodities	9
	3.1.1 Major Ports of Entry for Imported Goods	9
	3.1.2 Domestic Transportation of Imported Goods	13
	3.2 Estimation of Shipping Distance	15
	3.2.1 Sources of Information for Average Shipping Distances of Commodities by Mode of Transportation	15
	3.2.2 Methods for Estimating Average Shipping Distances	21
4.	SPILLS FROM BARGES	31
	4.1 Spill Risks from Barges	31
	4.1.1 Barge Design	32
	4.1.2 Barge Accident Statistics	32
	4.2 Quantity Spilled from Barges	35
	4.2.1 Amount of Material Shipped by Barge	35
	4.2.2 Average Quantity Released in Each Barge	35
	4.3 Human Exposure to Spills from Barges	40
	4.4 Environmental Releases from Barge Spills	40
5.	SPILLS FROM HIGHWAY TRUCKS	41
	5.1 Accident Type and Frequency	44
	5.2 Quantity Spilled from Trucks	50
	5.3 Human Exposure to Spills from Trucks	52
	5.4 Environmental Release of Chemicals Spilled from Trucks	53

Preceding page blank

B 395/10

TABLE OF CONTENTS (Continued)

		Page No.
6.	SPILLS FROM RAILROAD CARS	54
6.1	Spill Occurrences from Railroad Cars	54
6.2	Quantity Spilled from Railroad Cars	59
6.3	Human Exposure from Railroad Spills	59
6.4	Environmental Release of Chemicals from Railroad Spills	60
7.	DEMONSTRATION OF METHODOLOGY	61
7.1	Transportation Spills of Di-(2-ethylhexyl) Phthalate	61
7.1.1	Spills of DEHP from Railroad Tank Cars	61
7.1.2	Spills of DEHP from Trucks	63
7.1.3	Summary	66
7.2	Transportation Spills of Formaldehyde	66
7.2.1	Spills of Formaldehyde from Railroad Tank Cars	70
7.2.2	Spills of Formaldehyde from Trucks	72
7.2.3	Summary	73
8.	SUMMARY AND CONCLUSIONS	75
9.	REFERENCES	76